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UPON A NEW THEORY OF THE RETAINING WALL.*

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I wish in what follows to direct attention to a new theory of retaining walls, lately published by Prof. Weyrauch, of the Stuttgart Polytechnikum, in the "Zeitschrift für Baukunde," Band I, Heft 2, 1878.

The subject of retaining walls is one of special interest to the engineer and constructor. It is perhaps one of the most fertile subjects of discussion which come up for "periodical settlement" before engineering societies, and yet the subject does not seem ever to get settled. Every engineer knows, or thinks he knows, how to build a retaining wall, and yet nearly every engineer has a different theory as to how the wall should be proportioned. Perhaps no subject of applied engineering science has been so plastered over with theory and counter theory, and perhaps it is not too much to say that the treatment of no other subject has consequently brought upon applied mathematics so much opprobrium from the side of the so-called "practical engineer," who, disregarding all the abstruse formulæ and learned reasoning with which the subject has been encumbered, finds that with the aid of eyes and expe-

* Paper read before the New Haven Engineering Society, Oct. 25, 1878.

rience he can build, under any given circumstances, a very satisfactory wall without such help.

Hence he is prone to ask, and in such cases not indeed without reason, "What is the use of all this mathematical rubbish, anyhow?" and comes to make a practical, even if erroneous, distinction between "theory" and "practice" and to look with distrust upon the discussion of any case which involves the mysterious and all-pervading "x" and "y." That this is true with regard to many subjects of engineering science I think few will dispute. That it is especially true in the present case will, I think, be apparent.

Few engineers, however, need to-day to be told that the mathematics are only an aid to the reasoning faculties, enabling one to follow out to perfectly logical consequences a train of reasoning which would otherwise elude the grasp of the best trained mind. That they are an instrument merely, a means to an end, and that guiding intelligence and reason must ever control the mechanism. That "theory" is thus only the best reasoning of which we are capable by the use of all those aids which human ingenuity has given us, and is always just as true as its data, neither more nor less. That "practice" is, when worthy, always based upon such reasoning, and differs, if at all, only in that it does not make use of such aids generally or to such an extent, and is hence, if any distinction is made, rather more open to error in its conclusions, and not, therefore, *always* as true as its data.

In the validity of the data assumed, lies the strength of both, and the true reason of any popular distinction between them. Practice built up upon false data is but poor theory, and theory based upon false facts leads to bad practice. The "practical" engineer of to-day is, in common parlance, distinguished from the "theoretical," if at all, mainly by the superior accuracy of his data, drawn as they are from actual experience, and by his therefore superior comprehension of the practical bearings of any given problem, while he is often deficient in his logical methods. The theoretical engineer, on the other hand, although often possessed of superior accuracy in his logical methods, is handicapped by the lack of that experience necessary for a proper comprehension of the data essential to any given problem. Supply the defects of each and the distinction ceases to exist. Such a distinction the work of our technical and scientific institutions tends to render yearly less and less apparent and valid, and, from this point of view, the presenta-

tion of a problem, the history of which emphasizes very strongly the above remarks, cannot fail to be interesting and instructive.

I say the history of this problem of the retaining wall emphasizes well the above distinction between the theory and practice of engineering as represented by the engineers of to-day. For although, as I have said, the mathematician has devoted special attention to its solution, the history of every such attempt shows conclusively that the proper data have been disregarded, and premises have been assumed not warranted by facts. Here, then, is a lesson for many of us, viz.: to scrutinize closely our first assumptions and data before we set the mathematical machine at work, and never to forget that every result it grinds out is, after all, based upon an "if". If we put in error we cannot expect it to turn out truth.

This caution has not always been exercised, and the erroneous results are, and have been, taken by the practical engineer into his daily work, and have of course been found not in accord with fact. Hence a distrust in some directions of all theory and a falling back upon blind precedent and rules of thumb, than which nothing can be more fatal to all engineering progress. Here, then, we learn a second lesson, viz.: to remember that a formula holds good only under the same practical conditions as those assumed in its development, and can never be safely used except by one who thoroughly appreciates the premises upon which it is based.

Now let me endeavor to illustrate the above remarks by a brief history of what has been done by mathematicians upon this vexed problem of the retaining wall. Only in the light of such a review can we properly estimate the value and the points of difference of any proposed new theory. We shall first, then, pass in brief review the various solutions and point out wherein they fail to properly represent the case. For this purpose we shall not need to go into details or give results. It will suffice to confine our attention closely to the various assumptions upon which all former theories have been based.

In a small but exhaustive work by Prof. Winkler, entitled "Neue Theorie des Erddruckes," Wien, 1872, quite a full history of the various theories which have been proposed will be found. We shall condense from it, in what follows, as much as will serve our purpose, pointing out the fallacies of each theory as we proceed, including that of Prof. Winkler himself, as noticed by Prof. Weyrauch. We shall then briefly give the theory of Prof. Weyrauch and its results. Such a

course will enable us to properly estimate the value of these results and the real advance constituted by the new theory. My object will be attained if I succeed in calling general attention to this new theory and producing the conviction that Prof. Weyrauch, with characteristic acuteness, has hit the weak spot in all the hitherto accepted theories, has remedied it, and has thus produced a theory free from the defects of all preceding ones—a theory and, so far as I know, the only theory thus far propounded, which is based upon sound data, and which can therefore be considered as reliable.

I. History of the Subject.

Following, then, for the present, the history of the subject as given by Prof. Winkler in his *brochure* already referred to, two methods may be followed in determining the earth pressure upon a confining wall. According to the one, we consider a certain finite wedge-like portion or so-called "prism of rupture," which tends to separate from the rest of the earth and overturn or slide the wall; and, according to the other, we may consider the conditions of equilibrium of the earth particles and arrive at the total pressure by integration.

The first method is that which has generally been followed, and to it, therefore, we shall chiefly confine our attention. This method, that of the prism of rupture, we may, in view of what has been done, divide into two sub-methods.

I. The position of the surface of rupture is *à priori* assumed—ordinarily the same as the surface of repose.

II. This surface of rupture is determined under such conditions as make the earth thrust a maximum.

At first it was customary to assume this thrust as perpendicular to the wall, or, in other words, *friction was disregarded*. Later on it was recognized that this pressure, owing to friction, could not, in general, be perpendicular to the wall.

In all theories the surface of rupture is assumed to be plane, and the effect of cohesion is generally disregarded.

Let us now review briefly,

I. The Older Theories.

These we may state as

1st. *Theories which assume the natural slope as the surface of rupture —friction being disregarded.*

That is, the weight of the prism of rupture is decomposed into components parallel and normal to the natural slope.

Under this head we have the theories of Vauban (1687), Bullet (1691), Couplet (1727), Sallonnyer and Rondelet (1767), Tersac de Montlong (1774), and Blaveau (1767).

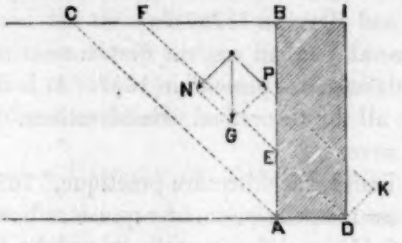
The French General Vauban was the first to treat retaining walls in his "Traité de la defense des places," in 1687. It is doubtful whether he was guided at all by theoretical considerations. If so, it is not known what they were.

Bullet, in his "Traité d'architecture practique," 1691, gives a primitive theory. He assumes the prism of rupture as bounded by a plane at an inclination of 45°, and decomposes its weight into parallel and perpendicular components. The parallel component he assumes to act directly upon the wall. He divides this by the height to get the thickness.

I need hardly point out the error of each and all of these assumptions. The inclination of the surface of rupture every practical engineer knows of his own experience, varies with the kind of material, the inclination of the wall and the slope of the ground. To assume it as constant, is to beg the whole question and to insert in the mathematical machine an assumption not warranted by fact. Of course, the results deduced are not then true, and are valueless. The method is an illustration of a tendency, perhaps not yet entirely eradicated, of assuming data carelessly, without sufficient regard to natural conditions and then building up an elaborate mathematical superstructure upon such shaky foundations. The same may be said of the decomposition of the weight of the assumed prism of rupture into parallel and perpendicular components, thus disregarding entirely the effect of friction. The division of the thrust by the height, in order to obtain the thickness, is again a pure assumption, which would invalidate the rest, even were it all true.

Couplet (1727) differed from Bullet only in taking the surface of rupture through the forward edge of the wall D, assuming the angle to be that made by a pile of balls, or the tangent of the angle of inclination of EF to be $\sqrt{8} = 2{\cdot}83$, assuming $AEFC$ to be supported by the portion of the wall ADE, and also in equating the moment of the thrust P about D to the moment of the weight of the wall. The deviations are improvements, but the whole method is open to the

same objections as Bullet's. The assumption as to the angle of repose shows an advance, in that it has reference to nature in some degree, and is not wholly drawn from "inner consciousness."



Sallonnyer and Rondelet (1767) followed Couplet in every respect, except that they took the surface of rupture through the rear edge, *A*, of the wall instead of *D*. They contributed, therefore, nothing, and practically no advance has yet been made by any one.

Tersac de Montlong (1774) simply returned to the 45° angle of Bullet, and only modified the views of Couplet and Rondelet by assuming the portion of *AEFC* to revolve the wall in one direction and the portion *EBF* in the other. The difference is of course only apparent, for the combined action is the same as that of *ABC*, and we have, therefore, Bullet's theory in fact.

Blaveau (1767) only differed from Bullet in that he decomposed *P* into a horizontal component, *H*, and a vertical component, *V*, and took the first as the pressure upon the wall. Still nothing is gained. No wonder that practical engineers should regard with distrust mathematicians producing such theories as these! Any man face to face with a bank of earth for the first time could detect the main error of these theories. "The parallel component," he might say, "is indeed the force which would slide the prism down along the surface of repose if there were no wall to retain it, but this force is opposed by friction, and in the case of the natural slope is just equal to the friction, so that there is nothing left to cause pressure upon the wall. Moreover, the angle of repose is incorrectly assumed." And such a position would be fully justified. What, then, have we thus far gained? Nothing but vexation of spirit for the practical engineer who wishes some better rule than a "rule of thumb," and masses of bristling formulæ to dismay the heart and confuse the mind of the docile and much-enduring student of engineering science.

A step forward was made by Coulomb in 1774, by the assumption

of a prism of greatest thrust, and yet, strange to say, we find even in recent times a return to the old exploded theories just mentioned, by Maschek, in 1842, and Hoffmann, in 1858. Hoffmann rejects the prism of greatest thrust, without giving any reasons for so doing, takes the surface of rupture through the forward edge for rotation, and through the rear edge for sliding, and decomposes in the latter case the parallel component into horizontal and vertical components. His theory thus has something in common with that of Couplet and of Blaveau, and is in no sense superior to either.

Thus we see that revivals of old and exploded theories are to be guarded against even now. A knowledge of what has been done in the history of the subject will enable us in any such case to relegate at sight all such revivals to their proper place—oblivion—no matter how thickly the mathematical and algebraic dust may overlie and obscure the fundamental data assumed. It is to be regretted that Hoffmann spent so much time in the calculation of numerous tables for practical use (!). The time might have been so much better employed in some more useful direction.

2d. *Theories which assume the natural slope as the surface of rupture —friction being taken into account.*

In this last clause we recognize a real step in advance. The first assumption, however, invalidates the whole argument, and all such theories, wherever we find them, we can promptly discard.

Belidor (1729) was the founder of this school or method. He *assumed* that, without friction, the normal pressure upon the vertical wall would be equal to the weight of the prism formed by the natural slope. Friction he *assumed* to consume just half of this pressure. He took the point of application of the pressure at one-third the height of the wall. Assumption upon assumption, as we see, all without any warrant of fact. The only real advance consisted in the simple recognition of friction as an important element of the problem, not in the manner in which he took it into account. It seems strange that so many able men should give earnest attention to the subject and not recognize at a glance what every practical engineer would recognize by instinct, viz., that the amount of friction must determine how much of the earth will break loose, slide down, and force the wall. Yet upon a first hasty consideration it seems natural to admit that the amount pressing upon the wall must be the same as that which would slide down if the wall were not there. Hence the general assumption

at this period of the natural slope as the surface of rupture—an assumption which implicitly ignores entirely the influence of friction.

After Belidor we have Gadroy (1745), Trincaux (1768) and d'Anthony. The two last took the point of application of the thrust at two-thirds the height of the wall.

Gauthey gives a theory which coincides with that of Blaveau, only he deducts one-third from the parallel component by reason of friction.

3d. *Theories which assume a prism of greatest thrust and an earth pressure normal to the wall.*

The founder of this school is Coulomb (1773). We have all heard of him and his theory. He gave an impulse to the theory of the retaining wall characteristic of real genius, which it has never lost. He did not leave out of sight the physical data of the problem, but took them into account in framing his theory. In other words, he conformed theory to practice. Nine-tenths, I suppose, of the theories at present accepted and in use acknowledge him as their inspiration. It therefore becomes us to use him with respect. Nevertheless, his theory and those of his followers are defective. With Coulomb we reach a point where real progress begins, not merely in conception but also in execution—the peculiarities of the problem are not merely recognized, as indeed they were by some of the investigators already named, but they are to a large extent properly met, and not satisfied by rough assumptions which only recognize difficulties without meeting them.

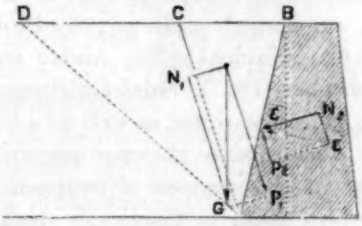
If we have shown anything thus far, we have shown that all preceding efforts from Vauban to Gauthey, were fruitless. So far as their labors are concerned they have been evil, and simply evil, because as we have seen in the case of Hoffmann and Maschek, their erroneous and totally valueless strivings are apt to turn up even in later times, with all the prestige of antiquity, to the confusion and botheration of the present generation.

With Coulomb begins a new era in the history of the subject. He did not reach the bottom, as has already been intimated, but he and his followers have moulded the formulæ which perhaps many engineers to-day use—if they ever use any—and he deserves, therefore, special mention. Let us try to make plain his method of dealing with the problem.

In the first place he took into account cohesion. This is a minor point and unessential to any theory, but yet necessary to be noted in

order to understand his method, therefore we notice it first. For it is evident that as cohesion helps the wall, a wall which is safe without it is so much the more safe with it. Its influence, moreover, is at best but slight, as every practical engineer knows, as the height at which earth will stand vertically without sliding is in general but slight.

According, then, to Coulomb's view, the surface of rupture is a plane, and along this plane surface a certain prism tends to slide. The pressure exerted by this prism upon the wall he *assumes* as normal to the wall. Here, then, we have at once the friction of the earth upon the wall disregarded. He decomposes the weight, G, of this prism and the reaction of the wall, E, into two components respectively par-



allel and perpendicular to the surface of rupture, and puts the difference of the parallel components, $P_1 - P_2$, equal to the resistance to sliding of the prism. This latter, however, consists of the friction, which is proportional to the normal pressure, N_1, only, and of the cohesion which is proportional to the surface of sliding only. If we take the co-efficient of friction, equal to f, and the co-efficient of cohesion, *i. e.*, the cohesion for the area unity, equal to c, and the breadth of the prism, BC, for horizontal earth surface (this is the only case Coulomb discusses), equal to x, we have for the pressure upon the wall when vertical (this also is the only case discussed by Coulomb):

$$E = \frac{\gamma\, h\, x\, (h - f\, x) - 2\, c\, (h^2 + x^2)}{2\, (x + f\, h)}$$

where h is the height of wall, and γ the weight of a cubic unit of earth.

Now, as Winkler goes on to say, Coulomb concludes in a manner by no means clear, that, as the surface of rupture is assumed in different positions, the corresponding pressure upon the wall changes. For one position only is this pressure a maximum. The "prism of greatest thrust" must always tend to separate, because that resistance which

would keep in place this prism would so much the more keep in place any other. He therefore differentiates the above expression with respect to x, and putting the differential co-efficient equal to zero, finds for the value of x, which gives the greatest pressure,

$$x = -fh + h\sqrt{1+f^2}.$$

That is, *the position of the surface of rupture is entirely independent of the cohesion.* The corresponding greatest pressure is, of course, easily found. The point of application of this pressure, cohesion disregarded, is correctly shown to be at one-third the height of the wall.

Such was Coulomb's method. It was taken up and followed out in its consequences to all cases of walls inclined at any angle, earth surface at any angle, surcharged walls, etc., by Prouy (1802), Mayniel (1808), Français (1820), Navier (1826), Audoy and Poncelet (1840), Hagen (1853), Scheffler (1857), Saint-Guielhem (1858), Culmann (1866) and Mosely in recent times, as well as a host of others whom it would be useless to name, since the same assumptions lie at bottom, and they only differ in elaborateness of treatment and detail.

The objections which apply to Coulomb's method apply to all, as upon that they all stand or fall. The work of Poncelet was especially elaborate, and his graphic solutions, which enable the practical man to handle the rather involved algebraic expressions which abound in all the theories of this school, have done much to make his name in connection with retaining walls familiar to all. Yet it may be doubted whether the theory, even as popularized by him, has made much real headway, and whether engineers to-day bother themselves much with calculations and determinations of stability, in the case of a wall.

There is evidently a reason for this, as engineers to-day, though not apt to spend their time in mathematical recreations, are pretty quick to search out and make use of any real and efficient aid, whether from the side of pure or applied mathematics, or from that of successful practice or well-established usage. If the theory of Coulomb and his followers has not, then, found a lodgement in the practice of to-day, it is pretty good *prima facie* evidence that it does not meet the requirements of the case, and that when tried by the touchstone of practice it has been found wanting. However, we need not decide the merits of the case upon such showing. Objections more specific may be urged. All the authors we have mentioned thus far, from Coulomb down, assume a prism of maximum thrust. They all stand or fall with that.

Now, as Winkler points out, several objections may be urged against this.

In applying this principle, we decompose the weight, G, of any prism limited by a plain surface, AC, into two components, E and P_1, acting upon the wall AB and the surface AC. Of these P_1 holds the friction and cohesion in AC in equilibrium. By this assumption E is determined for any *assumed* plane AC. E varies then with the assumed position of AC, and this position is so determined as to make E a maximum. Now here we have three objections.

1st. It is not apparent why the actual earth pressure should be exactly the maximum value of E for all positions of AC. No author, from Coulomb down, has given any direct satisfactory proof.

2d. The force P_1, as the wall gives way, equilibrates only in the plane or surface of repose, AD_1, while for every other plane P_1 is less than that necessary for equilibrium.

3d. E varies with the assumed position of AC, while nevertheless there can be really exerted upon the wall only one definite and constant pressure, entirely independent of the position of AC.

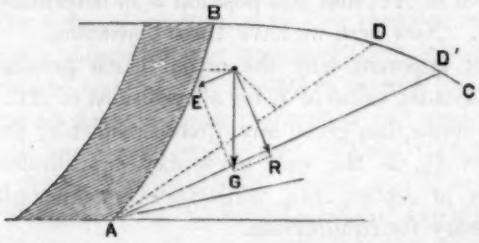
Any one of these objections invalidates Coulomb's theory, and leaves us still in the dark as to any satisfactory solution of the problem of the retaining wall. Engineering practice has, we think, thus decided, and the acceptable method has yet to be found.

There still remains a last method to be noticed, which is an improvement upon Coulomb's, and has proved the most generally acceptable of any. It is the theory of Rebhahn (1871), Winkler (1872), von Ott (1877), and is identical in its assumptions with the method followed by Ortmann, Scheffler, Rankine, Lævy, Considère and von Mohr, although these last proceed from a consideration of the conditions of equilibrium of the earth particles, and arrive at their results by integration. This we alluded to in the beginning as the second method of procedure, and as it is identical in its assumptions and results in the one we are about to describe, we may dispose of the two together.

Here, as in *all* the theories, we assume a plane surface of rupture. This is necessasy in view of our necessary ignorance as to what this surface really is. Moreover, as experiment and observation show, this assumption is practically correct.

The wall AB may have any shape and inclination, as also the earth surface BC. Acting upon the wall is a certain pressure E, which is properly assumed as invariable in the reasoning, no matter where the

surface of rupture may be first assumed to lie. We thus avoid the objections to Coulomb's theory. Moreover, the pressure is not taken as normal to the wall, but as making a certain angle to the normal. Thus we take into account, very properly, the friction of the earth upon the wall when motion is just taking place. Now here I wish to direct careful attention—for it is a vital point. It is argued, and with some show of truth, that when motion is just about to commence by



reason of the yielding of the wall, or just upon the "verge of equilibrium," as it were, this angle of the earth pressure with the normal to the wall *must be just equal to the angle of repose of earth on wall,* or if this angle is greater than that of earth on earth, then to this latter angle, since, then, as the wall moves, a film of earth adheres to it, and a line of separation is between earth and earth. It is therefore on these grounds *assumed* that the pressure E makes an angle with the normal to the wall, at the verge of equilibrium, equal to the angle of repose of earth on wall or of earth on earth. These are the only two assumptions of this theory. The first, that of a plane surface of rupture, is necessary and common to all theories; we cannot afford to quarrel with that in our present state of knowledge. The second is that the earth pressure makes with the normal to the wall the angle of repose or of friction, where equilibrium just obtains.

If, then, we suppose a prism limited by any plane, AD, we have three forces, the weight of this prism G, the earth pressure E and the pressure R upon the surface AD.

As AD changes its position, *i. e.*, as we assume it to take different positions, E is properly considered as constant, since the imaginary section cannot affect the actual thrust on the wall (here was Coulomb's error) while G and R vary. For any one position of AD, then, G is determinate, and hence for constant E the intensity and direction of R for that position of AD is fixed by the parallelogram of forces, since

E, G and R must be in equilibrium. This pressure R, thus found, may be decomposed into a normal N to AD and a parallel force S. The normal force gives the friction of N along AD, when f is the co-efficient of friction. If the length of the surface AD is l and the co-efficient of cohesion is c, then the total resistance to motion along AD is $fN+cl$. The force S tends to cause motion along AD. Now, to have equilibrium we must have for any and every section AD, the condition

$$S \lessgtr f N + c\,l.$$

For that section for which equilbrium *just* obtains and no more, we have

$$S = f N + c\,l \text{ or } \frac{f N + c\,l}{S} = 1.$$

This section is the surface of rupture. For all other sections

$$S < f N + c\,l$$

$$\text{or } \frac{f N + c\,l}{S} > 1.$$

For the surface of rupture, then, the condition is that

$$\frac{f N + c\,l}{S} \textit{ shall be a minimum.}$$

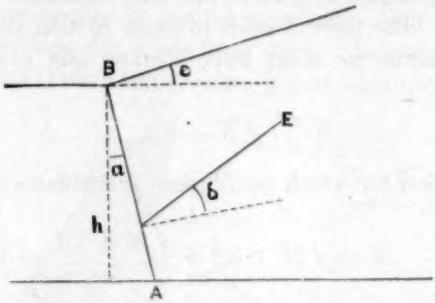
The surface of rupture is thus determined. G is then found, and then E.

This is, I think, a fair presentation of the last and best method which we shall notice—a method which to-day displaces Coulomb's, and which is to-day used in one shape or another by engineers, if they ever use any at all.

It rests, as we see, upon two assumptions, and only two. All objections must be made here or not at all, since the mere mathematical handling can be left out of sight. The first assumption, that of a plane surface of rupture, we must let pass, provisionally at least. It is fair to presume that its practical error is slight and more than balanced by neglecting cohesion, since the effect of this last is to help the wall. Let us direct our attention, therefore, to the second assumption, and see where it logically brings us out.

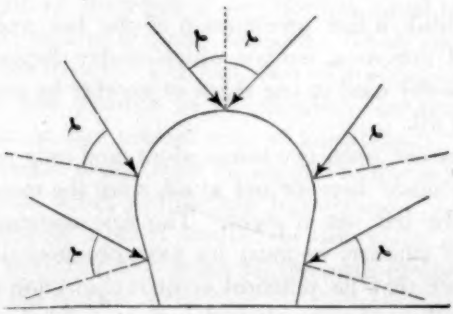
Prof. Weyrauch points out in the article referred to in the beginning of this paper the error of this assumption as follows. Let the angle made by the earth pressure E with the normal to the wall be δ, and

call the angle of repose φ. Coulomb and his followers for upwards of 60 years *assumed* $\delta = o$, or, as we have seen, took the earth pressure normal to the wall. Since Poncelet (1840) it has been the prevalent fashion to *assume* $\delta = \varphi$, or equal to the angle of repose. The



reasons for such assumption we have just given. We have thus passed in the history of the subject from one extreme to the other. Is it not possible that the truth may lie in the middle? Let us see!

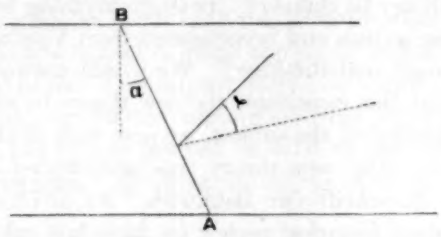
The assumption $\delta = o$ was made because there then seemed no reason to suppose it anything else. No one ever attempted to prove it, but simply assumed that if the pressure was not normal the earth would slide. Many recent writers, however, contend that δ must equal φ, for at the verge of motion the earth is just on the point of sliding.



Let us admit their reasoning on this point, and apply the principle to a special case.

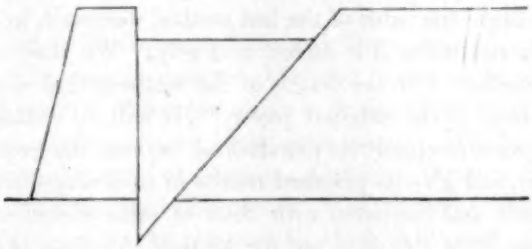
Consider an arch subjected to earth pressure. Then the earth pressure upon every element makes the angle φ with the normal at that point. Follow up towards the crown from either side, drawing

the earth pressure for different points, and we find at the crown two differently directed pressures at the same point, due to the same cause. Or, again; let us take a plane wall, AB. The earth pressure makes the angle φ with the normal to AB. Conceive the wall to turn about



A and take up different positions. For each new position the angle must be constantly equal to φ. Thus when the wall becomes horizontal the known *vertical* earth pressure must, according to our principle, still make the angle φ with the normal!

The principle is evidently not of general application, for it fails for horizontal position of the wall. Let the wall tip up again, at what position does the principle begin to hold good?



The assumption is evidently faulty. It does not represent facts, and the results of the theory built upon it cannot possibly, except by a balancing of errors not to be expected, be more correct than its data. Still the assumption *partially* represents fact. Thus to say that $\delta = \varphi$ is virtually to say that the wall slides out on its foundation only, and the prism sinks, as shown in the figure. For such a case the assumption would be correct. We must not, then, too hastily reject the theory *in toto*, but rather seek to estimate how and when to rely upon it, and when to reject it. This can be done only by comparison with the

results of a correct theory, which does not make use of this faulty assumption.

II. Weyrauch's New Theory.

Can such a theory be framed? Is there anything better to take the place of all these writers and investigators from Vauban and Coulomb to Poncelet, Mosely and Rankine? We would answer both questions affirmatively, and this constitutes the new theory to which, in view of the preceding history of the subject, we now wish in this paper to call special attention. The new theory was propounded by Prof. Weyrauch in the "Zeitschrift für Baukunde" for 1878 (Bd. I, Heft 2), and from the short historical review we have just taken, we are now in a position to estimate it at its true value, in so far as it claims to be an improvement upon all others, and only in so far as it does this, can it properly claim attention at all. Engineering literature, as we have seen, is too prolific upon this subject for any new theory to claim attention to-day unless its claims to such attention are well founded.

In the writer's opinion the new theory is in fact a real advance upon any hitherto advanced, and is free from the objections which apply to them. It is simple, and its results are practical. It enables us to properly estimate the value of the last method discussed, to show where it is at fault and when it is correct and why. We shall endeavor to present it briefly. For the details of the mathematical discussion the reader can refer to the original paper.* It will be sufficient for our purpose to examine closely its foundations, indicate the general method of discussion, and give its practical results in such shape that they may be used, tested and compared with those of other theories. Any one interested can then follow it out for himself, develope it further and add to its results. It remains, indeed, to be worked out into somewhat more practical shape for the working engineer, and to be applied to cases of surcharge, etc., but the foundations at least are laid, and seem firm.

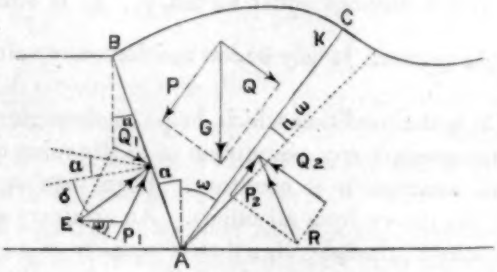
1st, then, we disregard cohesion, not that this is necessary to the theory, but simply that its disregard renders our results and algebraic work more simple and its introduction would not give any practical accuracy commensurate with the increased complexity of the resulting formulæ. Cohesion helps the wall a little. If we disregard it, a wall

* Zeitschrift für Baukunde, Bd. i, Heft 2, 1878.

which is safe by our method is simply still safer in reality. This assumption can then be granted us, for the sake of simplicity at least.

2d. We *assume*, and this is the *only* assumption we shall make, or which is necessary to be made, that the surface of rupture is practically a plane surface; that is, that all elementary forces acting upon any plane section through the earth, have the same direction or are parallel.

This single assumption of a plane surface of rupture is common to all theories. Without it we cannot start. We differ from all other theories in making no further assumption (that regarding cohesion is not essential). Let us now proceed to wind up and set in motion our mathematical machine. We give an outline of the manner in which this is done.



Let the surface of the earth have any form, and the wall AB any inclination. The earth pressure, E, makes some angle, δ, with the normal to the wall. What this angle is or should be we do not know as yet. We only say it must make *some* angle. We do not assume this angle to be the angle of friction. Conceive through the point A any plane section, as AC. The weight G of the prism ABC must be held in equilibrium by the pressure E, which this prism would cause on the wall, and the pressure R which it would cause upon AC. Wherever AC may be, if this prism ABC does not move, these are the forces which hold it in. We have then three forces in equilibrium. Let us decompose these three forces into components parallel and normal to AC. Then the necessary conditions for equilibrium are three, viz.:

The sum of the components parallel to AC must equal zero, or

$$P - P_1 - P_2 = 0 \qquad (1)$$

The sum of the components perpendicular to AC must equal zero, or

$$Q + Q_1 - Q_2 = 0 \qquad (2)$$

The sum of the moments of the forces E, G and R, about any point, must equal zero. Take the point of moments at A and let the lever arms be e, g and r respectively. Then

$$G\,g + E\,e - R\,r = 0 \qquad (3)$$

Also, if φ is the angle of repose of earth on earth,

$$\frac{P_2}{Q_2} \leq \text{tan. } \varphi \text{ or } \frac{P - P_1}{Q + Q_1} \leq \text{tan. } \varphi \qquad (4)$$

because if $\frac{P_2}{Q_2}$ were greater than tan. φ there could not be equilibrium. This, therefore, is one of the necessary conditions of equilibrium. Observe, $\frac{P_2}{Q_2}$ is not *assumed* equal to tan. φ. It is simply asserted that it cannot be greater. It may be less and have any value below this limit.

Equation (3) is the condition which helps us through our solution and renders unnecessary any assumption as to the value of δ. Without it such an assumption is necessary. Here then is the point of divergence of the theory from all others. An arbitrary assumption is replaced by a sound principle, viz., that of equality of moments.

It seems strange that this third condition of equilibrium should never before have been introduced into the problem, and that therefore resort has been had to a questionable assumption instead. Yet such is the fact.

Our mathematical machine is now wound up. All we have to do is to set it in motion and let it grind out for us the inevitable consequences of these conditions of equilibrium. Human fallibility in calculation aside, he who looks for a flaw in the entire treatment must look for it in these first four conditions and the single assumption upon which they rest—that of a plane surface of separation.

If, now, there is anywhere in the mass of earth any one section as AC, for which

$$P - P_1 = (Q + Q_1) \text{ tan. } \varphi \qquad (5)$$

then that plane is the true surface of rupture. The position of this plane is determined by the condition

$$\frac{P - P_1}{Q + Q_1} \textit{ shall be a maximum.}$$

If this seems like the same reasoning which we discarded when

applied to the wall, a little consideration will show the difference. There it was *assumed* that at the verge of motion the earth pressure made an angle φ with the normal to the wall. Here it is simply asserted that out of all conceivable sections AC, that one will be the real surface of rupture, for which the normal angle of R is the greatest consistent with equilibrium. This is undoubtedly true.

To find this position of AC we have to put, as we know, the first differential co-efficient equal to zero, or

$$\frac{d\left(\frac{P-P_1}{Q+Q_1}\right)}{d\,\omega}=0 \qquad (6)$$

From our figure we have for any position of AC,

$P = G \cos.\ \omega$, $Q = G \sin.\ \omega$, $P_1 = E \sin.\ (\omega + \alpha + \delta)$

$Q_1 = E \cos.\ (\omega + \alpha + \delta)$

We have then from (5)

$G \cos.\ \omega - E \sin.\ (\omega + \alpha + \delta) = [G \sin.\ \omega + E \cos.\ (\omega + \alpha + \delta)] \tan.\ \varphi.$

Since this equation holds good only for the surface of rupture, we have for the earth pressure upon the wall AB, when ω is the angle made by the surface of rupture with the vertical,

$$E=\frac{\cos.\ \omega - \sin\ \omega \tan.\ \varphi}{\sin.\ (\omega + \alpha + \delta) + \cos.\ (\omega + \alpha + \delta)}\,G = \frac{\cos\ (\varphi + \omega)}{\sin.\ (\varphi + \omega + \delta)}\,G \qquad (7)$$

We have then from (6)

$$\frac{d}{d\,\omega}\left(\frac{G \cos.\ \omega - E \sin.\ (\omega + \alpha + \delta)}{G \sin.\ \omega + E \cos.\ (\omega + \alpha + \delta)}\right)=0$$

If, now, we represent the length of AC by k, and let γ be the weight of a cubic unit of earth, then

$$d\,G = \tfrac{1}{2}\,k\,d\,\omega \times k\,\gamma$$

and by performing the differentiation we obtain

$$\frac{G}{E} - 2 \sin.\ (\alpha + \delta) - \frac{k^2\,\gamma}{2\,G} + \frac{E}{G}=0 \qquad (8)$$

Substituting the value of $\frac{G}{E}$ from (7) we have for the weight of the prism of rupture

$$G = \frac{\cos.(\varphi + \omega) \sin.(\varphi + \omega + \alpha + \delta)}{\cos.(\alpha + \delta)} \frac{k^2\gamma}{2} \qquad (9)$$

Substituting the value of sin. $(\varphi + \omega + \alpha + \delta)$ found from this equation in (7) we have for the earth pressure on the wall

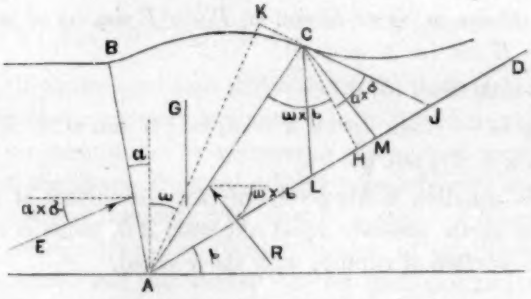
$$E = \frac{\cos.^2(\varphi + \omega)}{(\cos.\alpha + \delta)} \frac{k^2\gamma}{2} \qquad (10)$$

and since the sum of the horizontal components of E, G and R must be zero

$$E \cos.(\alpha + \delta) = R \cos.(\omega + \varphi)$$

hence

$$R = \cos.(\varphi + \omega) \frac{k^2\gamma}{2} \qquad (11)$$



It is now easy to prove the following relations: If AD is the natural slope, and we draw from the end C of the surface of rupture a line CI, making the angle $\alpha + \delta$ (or the angle of E with the horizontal) with the normal to AD, then the area of the triangle ACI is equal to the area ABC of the prism of rupture. If we lay off IL equal to IC, then γ multiplied by the area CIL gives the thrust E. If we lay off AM equal to AC, then γ multiplied by the area of ACM gives the pressure R upon the surface of rupture, all for one foot in length of the wall. That is area, $ABC = \triangle ACI$, or

$$G = \gamma \triangle ACI$$
$$E = \gamma \triangle LCI$$
$$R = \gamma \triangle ACM$$

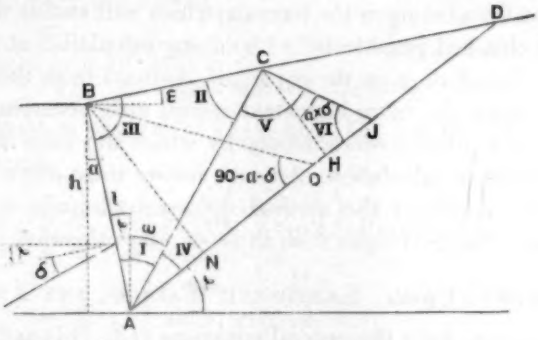
where the symbol $\triangle$ denotes "area of triangle." The first two of these relations were deduced by Rebhahn in 1871, under the assumption that $\delta = o$ or $\delta = \varphi$. They are here found to be true independently of any such assumption. The third relation is new and is due to our third condition of equilibrium. We have thus the relation

$$G : E : R = AI : IC : AC \qquad (12),$$

or the weight of the prism of rupture and the pressures upon the wall and surface of rupture are as the three sides of the triangle ACI.

We have made no assumption as to the value of δ. The value of this angle is given at once by equation (3), for any particular case. This equation, therefore, which is one of the necessary conditions of equilibrium, answers the same end as the unwarrantable assumption of $\delta = o$ or $\delta = \varphi$.

So much for the general case. For any special case we can now easily find G, E and R and the values of ω and δ. Let us suppose, for instance, that the earth surface is plane and slopes up at any angle ε. For this case it is easily proved that if BO is drawn, making an angle with the normal to the natural slope equal to $\alpha + \delta$, then AI is a mean proportional between AO and AD. We can, therefore, easily construct AC, provided δ is known.



The special value for E, in this case, becomes

$$E = \left[\frac{\cos.(\varphi - \alpha)}{\cos.\alpha}\right]^2 \frac{h^2\gamma}{2\cos.(\alpha+\delta)} \qquad (13)$$

We have also two equations containing ω and δ, by means of which each can be determined. The first is easily found from the figure to be

$$\sin.(\alpha+\omega)\cos.(\varepsilon+\omega)\cos.(\alpha+\delta) = \sin.(\varphi+\omega+\alpha+\delta)\cos.(\varphi+\omega)\cos.(\alpha-\varepsilon) \qquad (14)$$

The second is found to be

$$\cos.(\varepsilon+\omega)\,[\cos.(\varphi+\omega)\cos.\delta - \sin.(\varphi+\omega+\alpha+\delta)\sin.\alpha] = \cos.(\alpha-\varepsilon)\,[\cos.(\alpha+\delta)\cos.\varphi - \sin.(\varphi+\omega+\alpha+\delta)\sin.\omega] \qquad (15)$$

The point of application of the earth pressure is easily proved to be *at one-third the height of the wall from the bottom.*

We have not thought it necessary to give the details of the mathematical work by which these results are obtained. Our object is simply to point out in outline the method of discussion and to give briefly the practical results.

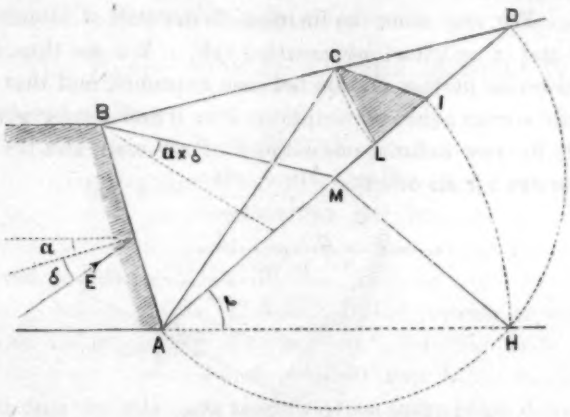
Equations (13), (14) and (15) include, then, every practical case that can ever occur, of wall inclined at any angle and earth sloping at any angle. They even include the special case of water pressure, for which ε, φ and $\delta = o$ and $\omega = 90°$. The theory is, as we have seen, free from objections which may be urged against all others, and is thus the best that has been framed. These three formulæ will enable any practical case to be easily solved, and though long they are sufficiently simple. In any special case, numerical data being given, they become quite short and easily worked. Of themselves, therefore, they constitute all that is needed, but of course in particular and special cases they admit of simplification, and for each special case we may deduce a construction founded upon the formulæ which will enable the desired results to be obtained graphically without any calculation at all.

We shall therefore give the equations, deduced from these general ones, which solve the more important special cases occurring in practice, and also the graphic constructions by which the same results may be obtained without calculation. Any one noting these down will have at disposal the results of the method upon a single page of his notebook, and can compare results with those of other theories.

I. General Case. Earth and Wall at any Angles.

For this case we have the general equations (13), (14) and (15), just given. In any given example we can find δ by equations (14) and (15), by finding ω in terms of δ from one, and inserting in the other. Having thus found δ, equation (13) will give us E, or the earth thrust, which is to be considered as acting at one-third the height of the wall from the bottom. We may also find E by construction. Thus, draw from the top of wall BM, making the angle $\alpha + \delta$ with the normal to the line of natural slope AD. Upon AD describe a semicircle, and draw MH perpendicular to AD. Make $AI = AH$. Then AI is a mean proportional between AM and AD. Draw IC parallel to BM and produce to intersection C with earth surface BD. Then AC is the surface of rupture. Make $IL = IC$. Then $\gamma \Delta ICL$ gives E. The direction of E is given by the angle $\alpha + \delta$. Its point of application is as given above. We can now find the moment of this thrust

with reference to the outer edge of wall and then determine what thickness the wall should have in order that its weight may more than counterbalance this moment by as great an excess as may be desired.



II. Earth Surface Horizontal.

Here ε becomes zero in (13), (14) and (15), and we have, after suitable reductions,

$$\left\{\begin{array}{l} E = \tan.^2\left(45 - \frac{\varphi}{2}\right)\frac{h^2\gamma}{2\cos.(\alpha+\delta)} \\ \text{or} \\ E = \frac{\tan.\alpha}{\sin.(\alpha+\delta)}\frac{h^2\gamma}{2} \end{array}\right. \qquad (16)$$

which latter will apply for any value of α not equal to zero, or when wall is not vertical.

We have also

$$\omega = 45 - \frac{\varphi}{2} \qquad (17)$$

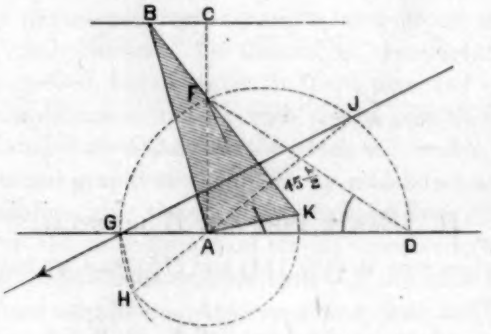
and

$$\left.\begin{array}{l} \tan.\vartheta = \frac{\sin.\varphi\sin.2\alpha}{1-\sin.\varphi\cos.2\alpha} \\ \text{or} \\ \tan.(\alpha+\delta) = \frac{\tan.\alpha}{\tan.^2\left(45-\frac{\varphi}{2}\right)} \end{array}\right\} \qquad (18)$$

the latter equation being in general most convenient to use.

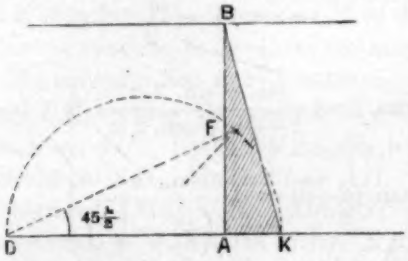
These equations are quite simple, and easily solve any case under this head.

It may also be easily proved by a discussion of the value for δ, that $\delta = 0$ only when the wall is vertical or horizontal, as evidently should be the case, while for $\delta = \varphi$, the wall must make the same angle on one side of the vertical that the surface of rupture does on the other, or $\alpha = \omega$. For any other inclination of the wall δ is intermediate between 0 and φ, as given by equation (18). We see thus, that here the truth does lie in the middle between extremes, and that for horizontal earth surface, the asssumptions $\delta = 0$ and $\delta = \varphi$ give correct results only for two definite inclinations of the wall, and results more or less incorrect for all others.



Instead of using the formulæ we may construct the earth pressure here, entirely without calculation, as follows:

Make $AD = AC$, and the angle $ADF = 45° - \frac{\varphi}{2}$. Construct a circle through F and D with its centre in AD. Draw GH parallel to AB. Produce HA to intersection I. Then IG gives the direction of



the earth pressure. Draw AK perpendicular to AB and make it equal to AH. Then $\gamma \Delta ABK$ gives the thrust per unit of length of wall.

If the wall is vertical the construction is simplified—thus:

Make $AD = AB$, and angle $ADF = 45° - \frac{\varphi}{2}$. Construct circle through F and D with centre in AD. Then $\gamma AAKB$ gives thrust, which of course is perpendicular to wall.

III. The Earth Surface has the Natural Slope.

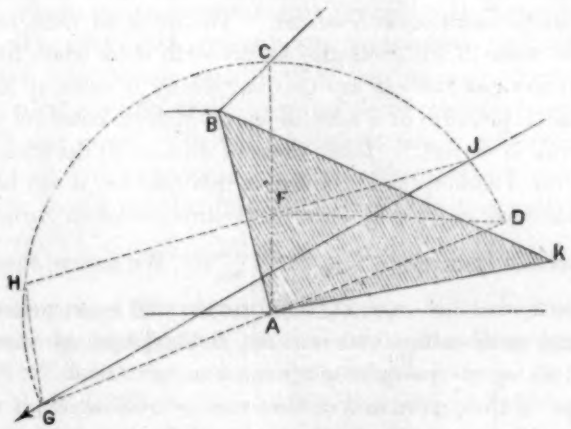
For this case we have

$$\omega = 90 - \varphi \tag{19}$$

$$\left.\begin{aligned} \tan.\,\delta &= \frac{\sin.\,\varphi\,\cos.\,(\varphi - 2\alpha)}{1 - \sin.\,\varphi\,\sin.\,(\varphi - 2\alpha)} \\ \text{or} \\ \tan.\,(\alpha + \delta) &= \frac{\sin.\,\alpha + \sin.\,\varphi\,\cos.\,(\varphi - \alpha)}{\cos.\,\varphi\,\cos.\,(\varphi - \alpha)} \end{aligned}\right\} \tag{20}$$

$$E = \left[\frac{\cos.\,(\varphi - \alpha)}{\cos.\,\alpha}\right]^2 \frac{h^2\,\gamma}{2\,\cos.\,(\alpha + \delta)} \tag{21}$$

We find that in this case, therefore, the assumption $\delta = 0$, is correct only when the wall makes the angle $\alpha = 45° - \frac{\varphi}{2}$ with the vertical, and that $\delta = \varphi$ when the wall is vertical only. For all other inclinations of the wall δ is intermediate between 0 and φ, and all other theories which give δ an invariable value are necessarily incorrect.



Instead of the above formulæ, which are, however, sufficiently simple, we may solve the present case also by construction alone.

Thus draw GAD parallel to the earth surface. With the vertical AC as radius describe a semicircle ADG. Draw DF horizontal and GH parallel to AB and then produce HF to intersection J. JG is the direction of the earth pressure. Make AK perpendicular to AB and equal to HF. Then $\gamma \Delta ABK = E$.

We can thus solve graphically those cases which occur most frequently in practice, while the formulæ themselves are by no means complex. In all cases the point of application is to be taken at one-third the height of wall from the bottom. The direction and intensity of E being then known, we can, for any case, easily find the thickness of the wall, which will give the moment of stability any desired number of times greater than the moment of rotation.

The Reliability of the New Theory.

And now, in conclusion, a few words as to the reliability of this new theory. Here we may let Prof. Weyrauch speak for himself: "It is, as we have seen, based only upon the single assumption of a plane surface of rupture. If it can be proved that this assumption is correct, then our theory is exact. A conclusion as to this point can only be reached by investigating the conditions of equilibrium of the earth elements. This is the method of Rankine, Winkler, Levy, Considère and Mohr, already referred to. Now this method proves that for an unlimited earth mass, without cohesion and with earth inclined at any angle, the above assumption *is* correct. The question, then, reduces to whether the same holds good also for an earth mass when limited by a wall. In any case, we can say that our theory is exact, if Rankine's theory of earth pressure in a mass of earth without cohesion and limited by a wall is correct." Both theories conduct to the same results, apart from the δ assumption. However this may be, it can be proved that the theory is correct at least for horizontal earth surface and a wall not inclined backwards, *i. e.*, for $\alpha \geqq o$. We arrive, therefore, at the conclusion, that for case II, the formulæ and constructions given for horizontal earth surface and wall not inclined back of vertical, *are mathematically exact and give perfectly accurate results.*" So much, then, at least, is clear gain, and as this case includes many, if not most practical cases, it is well to call attention to the accuracy of our method here.

If the wall inclines back, or α is negative, then, without doubt,

neither the new theory nor any other holds completely. The surface of rupture is then no longer a plane, and the earth pressure is still an unsolved problem. In all practical cases the difference is but slight, and our theory commends itself as the one involving the fewest assumptions. So much, at least, we know, that the earth pressure must be zero when the backward angle of earth with wall $\alpha = -(90-\varphi)$, because then the earth has the natural slope, and would stand, even without a wall.

To recapitulate, then:

For wall vertical or slanted forward we may use the results of I, II or III with confidence.

For wall slanted back, we must proceed still according as experience or custom may suggest or sanction.

The results hitherto given by older methods may be found from the new, by putting $\delta = \varphi$ or $\delta = 0$.

Such is, in brief, the new theory of the retaining wall to which we wish to direct attention. We have, of course, spoken from a purely mathematical standpoint. We by no means leave out of sight the fact that there are destructive agencies, such as water, frost and decay, which can never be drilled into any formula, and which can never be safely disregarded by any engineer. We do not forget that the earth mass is not always homogeneous, and that the "angle of repose" is a very variable quantity. We might go on to enumerate other disturbing conditions which no mathematics can grapple with, but it is scarcely necessary. The intelligent engineer, who understands how his formulæ are obtained, understands equally what they do not and cannot cover as well as what they do, and recognizes those conditions which experience only can meet. The only questions which arise are, whether he is better off with experience alone, or with experience *plus* theory? If the latter, should not the theory be as free from unnecessary assumptions as possible?

Suspension and Elevation of Clouds.—M. Oltramare supposes that the altitude of clouds is determined by the force of electrical repulsion between the clouds and the stratum of air below them. If the electricity is uniformly distributed, in accordance with any simple function of the height, the hollow sphere of air above the cloud can exert no influence.—*Comptes Rendus.* C.

A SYSTEM OF ELECTRICAL STORAGE.

By Profs. EDWIN J. HOUSTON and ELIHU THOMSON.

The various suggestions which have hitherto been made for the storage of electrical energy, in such manner as to readily permit its after recovery in the form of electrical current, have failed when attempted to be carried into practice, either on account of their inherent impracticability, or by reason of the serious inconveniences and losses due chiefly to the following:

1st. The extent of conducting surface of the storage apparatus required to be acted on, rendering it cumbrous.

2d. The loss of energy due to evolution of gas during the operation of charging.

3d. Lack of constancy and duration in the currents evolved after charging.

4th. The limited capacity for storage due to the proportion of active material being but a fraction of that present.

The well-known Planté Secondary battery is open to all of the above inconveniences, and though admirable in its conception as a piece of scientific apparatus, yet lacks markedly the requisites of an economical reservoir for electrical action. In the secondary battery, as is well known, the duration of action is chiefly dependent upon the amount of surface of the lead plates employed; the action of the current used to charge it being practically limited to the surfaces of the plates, and the charge received may therefore be designated as due chiefly to polarization. Moreover, the charge received is necessarily limited on account of the evolution of gas.

It is manifest that a Smee cell, or cell with vertical plates, in an acid solution, could not be used in the process, for the only effect would be the evolution of the gases hydrogen and oxygen from the decomposition of water.

In the system of electrical storage devised by us, the duration of action and consequent capacity for storage is independent of extent of surface and dependent on the mass of material to be acted upon.

In our method we employ a saturated solution of zinc sulphate, enclosed in a suitable vessel, at the bottom of which is placed a plate

of copper, to which is connected an insulated conducting wire. At or near the top of the vessel, and immersed in the solution contained therein, is placed a second copper plate, or plate of hard carbon, or metal unchanged by contact with zinc sulphate solution, and less positive than metallic zinc. This is also connected to a wire. The storage cell so constituted is then ready for charging, which is effected by the passage through the cell of a current, whose direction is from the lower to the upper plate. The current employed is that obtained from a dynamo-electric machine, and the result produced is the deposition of metallic zinc on the upper plate, and the formation of a dense solution of copper sulphate overlying the under plate. The duration of the charging action is of course limited only by the amount of zinc sulphate and the thickness of the lower plate. The cell, after charging, constitutes in fact a gravity cell, and continues a source of electrical current until a reconversion of all the copper sulphate into zinc sulphate has been effected, metallic copper being deposited on the lower plate, and the deposit of metallic zinc being removed from the upper. It thus may be allowed to regain its original condition. The recharging, however, may be effected at any time, either before or after the cell has become inactive. The cell may be covered or sealed to prevent evaporation; and since no addition of new material is needed, a restoration to an active condition is at any time possible.

It is not necessary to employ zinc sulphate as the material to be decomposed, since other metallic salts may serve the same end, the only other requisite being that the lower plate shall yield to the solution a metal capable of redeposition, and the solution of which is denser than the solution employed in the cell, and that the upper plate be capable of receiving a metallic deposit and of retaining its form unchanged during prolonged use.

A, Fig. 1, represents a cell of glass, or other suitable material, furnished with two metallic plates, *B* and *C*, connected separately by conducting wires to the binding posts, *b* and *c*, the wire from the lower plate being insulated. A porous diaphragm, *E*, is placed below the upper plate, *C*, to prevent fragments of deposited zinc from falling on the lower plate, which may occur should the charging current be too intense.

In charging, the arrangement of the cells in multiple arc or in series may be adapted to suit the electro-motive force of the dynamo-electric machine employed. The arrangement of the cells in charging may

be different from that in discharging, according to the purpose for which the current is designed. Diffusive action of the solutions may be prevented by any of the well-known means used in gravity cells.

Fig. 1.

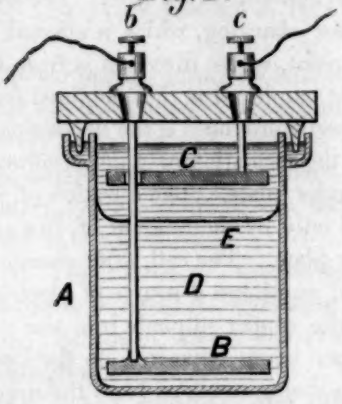
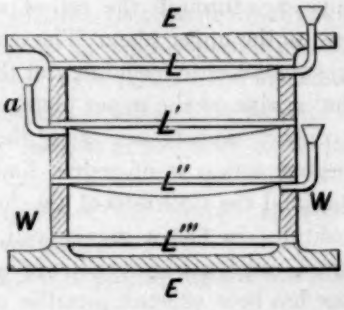


Fig. 2.



It may be objected that the economical results obtained in the storage of electricity as above described will necessarily be low, as but a fraction of the electrical energy in charging will be expended in overcoming counter electro-motive force, or in effecting electrolysis, compared with that which overcomes the resistance of the liquid, and therefore lost in heat production. But this objection is readily met by so connecting the cells as to make their counter action or counter electromotive force the chief resistance to its passage. Economical results necessarily follow, the economy attained being measured by the relative cost of the fuel required to drive the dynamo-electric machine and that of the zinc and chemicals used for charging a battery of equal power to that of the storage battery used.

The resistance of the liquid between the plates of a storage cell may be lowered either by broadening the cell or by bringing the plates nearer together. In charging, economical results are obtained by using the plates comparatively near to each other, and separating them during discharge, and thereby avoiding loss by diffusion.

A convenient form of storage battery, designed for rapid charging and discharging, is shown in Fig. 2, where L, L', L'', L''' are horizontal plates of copper separated by insulating rings, W, W, the spaces between the plates, L, L', etc., being filled with a saturated solution of

zinc sulphate. Lateral tubes, *a*, are provided to compensate for the expansion of the liquid due to changes of temperature, and also to provide for filling the cells. The cells are held between plates *E E* by bolts which pass from one to the other. In this arrangement, the plates *L'* and *L''* serve as upper and lower plates, accumulating copper sulphate on their upper surfaces and receiving metallic zinc on their under surfaces. The series may of course be extended.

When a number of cells are connected in series, several of them may be charging, while the remainder are used as a source of active current.

The most obvious application of a storage battery furnishing a constant and lasting current, is to replace the ordinary telegraphic batteries; the objections to the direct use of the dynamo-electric machine being mainly the necessity for continually sustaining the driving power and preventing variations or intermissions therein; to adapt the current generated to the work to be done; and to sustain a uniform electro-motive force in said current. By the use of a storage battery, the dynamo-electric machine may be run at suitable intervals to produce and sustain the charge of said battery. The economy and convenience of this arrangement will, we believe, be vastly greater than with the ordinary batteries in use.

In lighthouses, a dynamo-electric machine can be run by suitable power at intervals during the day to furnish an unfailing and reliable source of current for lighting purposes.

The purposes for which the storage batteries may be applied are so numerous that mention need not be made of them, the feasibility of each being decided by the question of its economy.

In domestic economy it would be feasible to provide storage batteries to be charged by dynamo-electric machines from convenient central locations, the energy of said batteries to be used in the operation of burglar and fire alarm systems, or for light driving power.

It is practicable in good forms of dynamo-electric machines to realize in external work from 50 to 60 per cent. of the power used in driving them. Of this we believe it possible to store and recover 50 per cent., or even more. Therefore 25 per cent. of the original power may be given out secondarily as electrical current. If it be assumed that in the best steam engines it is possible that 20 per cent. of the heat energy of the coal be utilized, then about 5 per cent. of the heat energy might, we think, be recovered after storage as electrical current.

Notwithstanding this small percentage, the economy would be much superior to the employment of zinc and other materials used in the ordinary battery in the production of current.

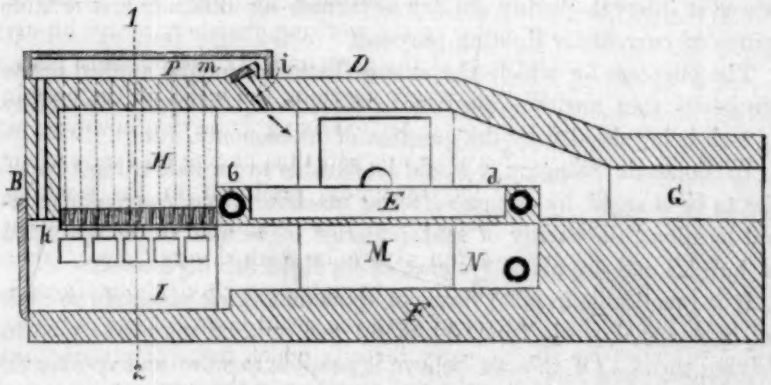
CENTRAL HIGH SCHOOL,
Philadelphia, November 22d, 1879.

IMPROVED PUDDLING AND HEATING FURNACE.

By JAWOOD LUKENS.

Read before the Franklin Institute at its meeting Oct. 15th, 1879.

The working of the furnace is as follows: The blast from a fan or blower enters the ash-pit, either in the ordinary way, by a pipe at one side, or, preferably, is blown into the air-chamber, *M*, under the bottom plates, and, passing along through the chamber, becomes heated considerably, and at the same time cools the bottom plates somewhat, thus protecting the working bottom of the furnace. The blast may be passed through the chills of the furnace before entering the air-chamber, *M*, and thereby become heated; this, however, is not necessary to the successful working of the furnace. Of the blast entering



the ash-pit a portion is carried up through the grate bars and fire to support combustion in the fire-chamber; while another portion passes, by means of the vertical pipes or passages in the walls, to the air-chamber, *P*, on top of the furnace. In passing from the ash-pit to the air-chamber on top, the air becomes highly heated and at the same

time serves to cool the walls of the fire-chamber, thus protecting the brick-work by keeping the temperature below what it otherwise would be. The air while in the air-chamber on top becomes still further heated by taking up heat from the bricks of the roof, thus keeping them cooler than they otherwise would be. From the air-chamber on top, the air, highly heated, is driven through the inclined tuyeres or openings in the roof, into the working chamber, producing rapid combustion of the gases and smoke passing over the bridge wall from the fire-chamber, and intense heat just at the point where it is needed, and at the same time deflecting the flame towards the bottom of the working chamber, and the metal to be operated upon. This depression of the flame tends also to save the brick-work over the working chamber. The combustion in the fire-chamber being less than in an ordinary furnace, the heat there also is less, which lessens the formation of clinkers and destruction of the brick-work. The force of the blast passing through the coals being less, the flame does not strike the roof with the same force as ordinarily, and consequently the wear of the bricks is not so great on this account. The actual result of this saving of brick-work has been found to be great, the brick-work of the fire-chamber lasting much longer than formerly. By means of the valve in the tuyeres the amount of the top or secondary blast can be regulated and proportioned to that passing through the grate bars exactly as required. The top blast entering the working chamber, *always* highly heated, immediate combustion of the gases and free carbon takes place, and no loss results from free oxygen reaching the metal on the hearth, as would otherwise be the case. An oxidizing flame can, however, be produced by working with a clear fire, and thus having an excess of air enter. By reason of the increased heat produced in the working chamber of the puddling furnace, the time required for the operation is reduced and the furnace can always be worked very "close," thus preventing waste of metal from oxidation. Having the furnace always at the required degree of heat, the metal is drawn out in better condition than from the ordinary furnace, which frequently works too cold, and the ball consequently goes to pieces in the squeezer.

In placing this improved puddling and heating furnace among the valuable improvements in iron manufacture, the claim is not made for economy of fuel only, nor is any claim made for its being the most economical in this respect. But the combined advantages over

the ordinary forms of such furnaces are deemed worthy of consideration. The great bulk of iron puddled and reheated is worked in the ordinary furnaces, either with draft or blast, with a reckless waste of fuel; and although there are many kinds of improved furnaces, claiming to do the work on miraculously small quantities of fuel, not one of them has been generally brought into use; either on account of expensive alterations and necessary changes of the arrangements of mills already built, or difficulty of manipulation and expense and annoyance of instructing workmen properly to use them, or for some other reasons. This furnace, while being sufficiently economical, compared with the ordinary furnace, to make a great saving in the cost of manufacture, has none of these disadvantages. The cost of construction, or changing from the old furnace to this, is so small as to be unimportant. There is no risk of trouble or annoyance in making the change, as the furnace could be used in the ordinary way simply by shutting the top blast damper. It requires no resetting of furnace plates or change of foundations; no alteration of the size or shape of the old furnace, but merely rebuilding of the fire-chamber, with the addition of the few pounds of iron work required in the construction. The advantages of the furnace are many, viz.: A saving of fuel, of from 25 to 40 per cent. A saving of ore "fix" of from 5 to 10 per cent. A less waste of metal in puddling of about 2 per cent. A much longer run of the furnace without repairs. A saving of labor required in working the furnace. Shortening of the time required for the operations going on in the furnace. Better condition of the iron when drawn from the furnace. Obviating, in heating furnaces, the evil of "blowing over" coal dust, and obtaining a clean, soft heat for pile or billet, and thereby to a great extent avoiding defects in the plate or shape to be rolled. The working of the furnace requires no special instruction or training of the workmen, any ordinary puddler or heater being able to work the furnace successfully.

The result of more than a year's use of these furnaces has demonstrated all of the foregoing assertions to be facts, and has shown that with them, as compared with the ordinary forms, more and better iron can be produced with less fuel, less "fix," less cost of brick-work and less labor in about the proportions set forth above.

STEAM BOILER EXPLOSIONS.

By E. A. CORBIN and H. G. GOODRICH,
Agents of the Hartford Steam Boiler Inspection and Insurance Company.

In the JOURNAL OF THE FRANKLIN INSTITUTE for October last appears an article on "Steam Boiler Explosions," referring to the late disaster at the Messrs. Wilt & Sons, which we desire particularly to notice, because it contains several erroneous statements of fact as to the exploded boiler, and which, as written and illustrated, will certainly mislead readers as to the particulars of the boilers of Mr. Campbell, referred to in said article.

The writer of this article says there were "three necks" to the Wilt boiler, that these necks leaked, that they were the weakest parts of the boiler, and that the boiler burst at the necks. The facts are, the boiler had *four* necks, the exploded boiler showed no sign of incipient rupture at the necks, and no such cracks in the sheets, or sheared or broken rivets at these seams; there were no known leaks at the necks, and no evidence of any on the sheets to which the necks were secured. Three of the necks remained intact, fast to the upper boiler; one of them was torn open by the separation of the two boilers during the progress of the explosion, while all of them were torn in the solid part at and above the angles at the lower boiler, and at no place on any of the necks were the seams parted, neither those seams which held the necks to the lower boiler, nor their longitudinal seams. They were all single riveted.

The leak referred to in the direct testimony was at the tube ends, and from a break in the rear tube sheet, in a line between the centres of two adjacent tubes; the fractured part, which had been mended by a lap strip bolted on, passed through the explosion without being disturbed.

The writer continues: "The two new boilers made for Wilt & Son are constructed upon nearly the same principle as that of the exploded one."

It is proper, we think, to qualify this word *nearly*. The exploded boiler consisted of a horizontal tubular boiler filled with tubes, connected at its top to a similar horizontal boiler, without tubes, by four

wrought iron necks; atop of this was connected a horizontal steam drum by two wrought iron necks. The water was carried near six inches above the middle of the second boiler.

The new boilers consist each of one horizontal boiler with tubes in its lower half, having the water carried a few inches over the top row of tubes, leaving nearly half of the boiler for disengagement and distribution of steam; over this boiler is mounted a horizontal steam drum, connected by two wrought iron necks.

The former is the type known as the "double-decker;" the latter is the plain horizontal tubular type, each provided with a steam drum.

Referring again to the explosion, we are fully assured by the results of the disaster that the rupture was mainly through solid iron, and independent of the known weaker lines along the rivet holes of the seams of the necks, showing conclusively that no initial rupture at the necks, such as stated by the writer of the article, occurred. The initial rupture, so far as known, was along the longitudinal seam at the side of the tubular boiler, where the old and new plate joined, and from thence went tearing through the strongest portions of the sheets, utterly regardless of seams, necks or anything else, and there was no line of fracture that in the least degree gives any ground for the theory that the necks were the weakest parts, certainly not to the forces in action during the explosion.

In all, there were sixty-three lineal feet of torn sheets, of which only two feet were along the longitudinal seam at the side of the tubular boiler. It is to this seam that all the evidence points as the place where the explosion began, the very place of all others in the boiler where the strains caused by contraction and expansion of the sheets, by the greater heat imparted to the lower half of the boiler, would act in the severest manner.

Nine years of constant use for a boiler of well-known qualities for rapid generation of steam, fired with shavings in the usual way by an engineer of known carefulness and efficiency, in the employ and under the constant supervision of the Messrs. Wilts, who never left any duty undone, nor spared expense, nor ran any risk, if the least sign of danger appeared, but ordered repairs done at once, and whose motto was "safety at whatever cost"—even such treatment, in the best wisdom of man, might wear out any iron structure. Nevertheless this *is* true; when in the full tide of business, with every appliance in the best of repair and in successful operation, as reported by the engineer the evening

previous to the explosion, who said to Mr. Wilt, "Every thing is in tip-top order," who will tell when and where rupture will begin?

Moreover, this boiler was carefully and thoroughly inspected by us a short time previous to the explosion, when no visible sign of weakness manifested itself. There was little or no wasting away of the sheets by corrosion, very slight scale in the boiler, not a defective rivet, nor a crack to be seen. There was not the first evidence of defect, decay or weakening visible, nor any change as regards safety from what was fully known of the boiler during all the past nine years of its use while under our care and inspection.

In addition to this testimony, we have the statement of the City's Chief Inspector to the effect, and with full knowledge of all the details of the exploded boiler, that had he with present knowledge made personal examination of this boiler the day before the explosion he could not have found defect anywhere, and would have passed the boiler as safe under 80 lbs. of steam, the same as we had done, declaring, also, that the repairs were properly made, that no weakening could possibly result from the blisters in the sheets (as proven by all of them going through the explosion without change), that no defective rivets were to be seen, that there was no visible deterioration of the sheets, that no damaging scale was anywhere to be found, and that no question was raised about the manner of securing the tube ends.

The testimony of the explosion silenced all speculations about the tubes, by demonstrating conclusively that the shell burst asunder before they gave way; that is to say, the boiler was exploded while the tubes held on, but they finally yielded to increasing pressure when the shell was torn.

Since the explosion, specimen pieces, cut with and across the grain, have been taken from each and every sheet for testing. The result given by competent men who experimented in all fairness, considering the elasticity as well as the tensile strength, proves that "no fault can be found with the iron" in this boiler.

A writer in Jour. of Frank. Inst. for August last says:

"The proportion and operation of the two safety valves were all that could be wished. The competency and carefulness of the engineer was maintained by all witnesses. No blame could be attached to any one, with any fairness, for the occurrence of this disaster."

With those who have studied the details of this explosion carefully, seeking for the truth alone, there can be but one true verdict, and that

is, that the makers of the iron, and the makers, users and inspectors of this boiler have done their best throughout. More than this men cannot do.

The "Report on the Explosions of Steam Boilers," in JOURNAL OF FRANK. INST., Dec., 1836, p. 364, says: "There can be no doubt that the strength of boilers may be diminished by constant and often unequal pressure, by which the material is injured so far as to give way under a less strain than that which it may once have borne." Further on in this most interesting and thorough "Report on Strength of Materials for Steam Boilers," August, 1837, p. 103, we find the following words, under the head of "Effects of Use and Long Exposure on the Strength of Boiler Iron": "This topic may be regarded as one of the most important which came under the notice of the Committee."

It is subject of regret that more was not done by the jury to ascertain beyond doubt the effects of long use of the iron in question; more especially interesting in this case, as the wasting of the iron by corrosion was very little, as was also the visible weakening of the joints and plates, which would at once suggest the probability of molecular change in the iron under heat and strain, an infirmity to which all iron under repeated strains is liable, and which even now is among the less known phenomena of metals.

The tensile strength per square inch of the test pieces cut from the used boiler plate reported by the Franklin Institute Committee, referred to above, show figures ranging from 46,000 to 54,000 lbs., which are singularly near to those of the results of tests of the exploded Wilt boiler plates, but no results are recorded by the committee of tests for ascertaining the elasticity of the metal under strain —an essential requisite of good boiler plate.

No tests of either set of experiments show a tensile strength less than 40,000 lbs. per square inch, and with such material it is easy to figure up a resistance in the Wilt boiler of over 300 lbs. per square inch of boiler pressure under uniform temperature of all the parts. As this boiler carried a pressure of not over 80 lbs., to which the safety valves were adjusted, there would be still a factor of safety of near 4 to 1, which ought to hold securely against rupture.

In view of all these facts, there appear two presumptive causes favoring rupture—diminished elasticity in the metal, and strains far

beyond those of boiler pressure, induced by the irregular action of the heat upon the boiler shell.

The writer further says that the Hartford Boiler Insurance Company objects to necks made of material heavier than that in the boiler. We most emphatically do, and whenever we are requested to supervise the construction of new boilers shall always so dictate. He also cites an instance where we have boilers insured with cast iron necks. Very true; but he must bear in mind that we have to take boilers as they are, and while a cast iron neck is not a defect sufficiently serious to cause old boilers to be reconstructed (especially where it is used at a low pressure and for light service), it is one that we are bound to remedy when building new ones. We have many boilers of faulty construction under our care, but that is no reason for perpetuating errors in the construction of new ones. We are very glad that he has seen fit to refer to his report on the boilers built for Mr. George Campbell, as events have transpired subsequent to that report which show, beyond question, what the result of his inspection led to. The boilers were built by the Baldwin Locomotive Works, according to specifications furnished by Mr. Barnet Le Van, who was employed by Mr. Campbell as an expert for that purpose. The boilers were of the type known as horizontal tubular boilers. The lower cylinders being 54 inches in diameter and containing 50 4-inch tubes; the upper cylinders were 30 inches in diameter, and they were connected by two 12-inch necks. When the boilers were finished and our inspectors were called in, preparatory to insurance, it was found that the upper row of tubes in the lower boiler came within 8½ inches of the top. Allowing for 4 inches of water above the tubes, the surface for disengaging steam was so small that it was apparent to us that nothing could keep the water at an even height or prevent it from being driven altogether out of the lower boiler at times. We immediately declined to insure the boilers, and so informed Mr. Campbell, who, naturally desiring further light upon the subject, referred the matter to various experts, and among those so consulted was Mr. Nystrom, as shown by the following letter:

"PHILADELPHIA, Aug. 29th, 1879.

"GEO. CAMPBELL, ESQ.:

"SIR—Your letter of the 25th inst., asking information about certain steam boilers, was duly received. I have inspected the boilers,

and submit herewith the report on same. Your letter contains three distinct questions, namely, as follows:

"1st. The chief objection offered against them is that there is not sufficient room or space between the top row of flues and the shell or top of boiler, which will cause the water to lift when in operation.

"2d. Are the necks large enough?

"3d. Are the boilers perfectly safe for constant use on my premises?

"REPORT OR ANSWER.

"1st. The height between the flues and top of shell is 9 inches in the centre, and allowing 4 inches of water on said flues leaves 5 inches between the water surface and top of shell. The relieving surface, or water surface, will then be $2{\cdot}59 \times 14 = 36$ square feet, which is sufficient to pass the steam without lifting the water; some mist or foam may rise with the steam through the necks, but that will at once be evaporated in the superheating vessel above. The water level in the boiler need not vary more than an inch or two above or below the mean level, which is assumed to be four inches above the flues. The objection quoted in the first question is therefore considered to be unimportant.

"2d. The necks are large enough, being $11\frac{1}{2}$ inches inside diameter, or $103{\cdot}8 \times 2 = 207{\cdot}6$ square inches, whilst the steam passage from the drum is only 4 inches in diameter, or 12·56 square inches.

"3d. The question if the boilers are perfectly safe for constant use required a perfect examination of their construction, workmanship and materials, in order to find out their weak or weaker points, which examination has been made, and it is found that the unions of the necks with the shell and drum are their weakest points, or the points where the boiler would first give way, or burst, under excessive strain. These unions, however, are as strong, if not stronger, than generally made in boilers of the same class. The extra good quality of materials and workmanship with which the boilers are made make them much stronger and safer than are other boilers of similar construction.

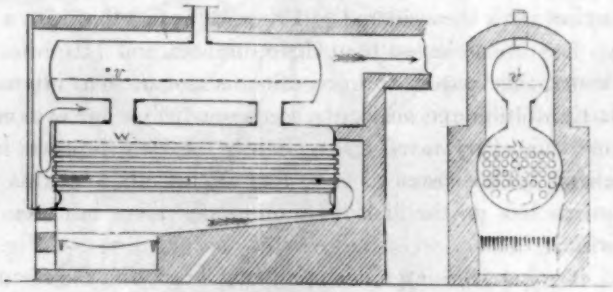
"(Signed) JOHN W. NYSTROM."

Now what was the result? Encouraged by such teaching as the above, Mr. Campbell was induced to put in two of the boilers as at first constructed under Mr. Le Van's specifications, and when they were fired up the effect was precisely that foretold by our inspector, and the water, instead of showing a variation of an inch, as stated by

Mr. N., a 12-inch glass gauge was not long enough to keep track of it, and no amount of persuasion could keep the water in the lower boiler when fired as originally intended. After several ineffectual attempts to remedy the fatal defects, the boilers were placed in the hands of the Hartford Boiler Insurance Company for such reconstruction as we thought necessary to make them work satisfactorily.

The reader is referred to the illustrations, Figs. 3 and 4, herewith reproduced from the October number of the JOURNAL, for comparison. They will show which they represent, the boilers originally made for Mr. Campbell, or those now in use at his factory.

Fig. 3. Fig. 4.



At our direction the Le Van boilers were entirely overhauled, changing their length to 18 feet instead of 14, and putting in 28 4½-inch tubes, leaving a clear space of 18 inches from top of tubes to shell of boiler. We also enlarged the necks, to save putting a man-hole on the top of the lower boiler. It was at this point that we stipulated what thickness of material should be used in the necks.

Three of the boilers, as altered under the supervision of the Hartford, are now in place and running, giving entire satisfaction in every respect.

White Shellac Varnish.—Dissolve 1 part pearlash in about 8 parts water, add 1 part shellac and heat the whole to the boiling point. When the lac is dissolved cool the solution and impregnate it with chlorine until the lac has all settled. This precipitate is white, but the color is due to the washing and starching. When it is dissolved in alcohol it forms a varnish which is as transparent as any copal varnish.—*Fortsch. der Zeit.* C.

PERREAUX'S STEAM TRICYCLE.

By Lewis S. Ware, M. E.

It is to be regretted that up to the present day but little has been done for the general improvement in the type of the tricycle, and the friction of the wheels, on general principles, is such that the advantage over the bicycle does not in any way exist. It is true the principles of equilibrium need not be understood, but the animal force consumed to cover a given number of miles is an item of the first importance when practical work is considered. In view of the fact that with a bicycle a mile has been made in less than three minutes, and 110 miles in less than 8 hours, this system of locomotion is not without interest. At the Paris Exhibition and since, Mr. Perreaux before our eyes mounted his tricycle, moved by steam, and evidently a certain progress has here been realized. The steam bicycle, also an invention of this gentleman, requires less power; 15 to 18 miles per hour has been accomplished with it. The tricycle, that we will now examine (see Fig. 1), has less speed, it going 10 to 13 miles per hour. Supposing the steam generator but moderately heated, the pulling force of this type is 13·2 lbs. The heated air from the generator, etc., moves in an opposite direction to the vehicle, and in no way interferes with the comfort of the rider. The cylinder of the motor has an interior diameter of 20 to 30 mm. (0·78 inch to 1·78 inches), with 80 mm. (3·14 inches) stroke of piston. The distribution of steam is accomplished by a slide-valve, opening and closing at points corresponding to the extreme travel of the piston.

The water-pump can be worked by a small side lever, and with but little care the water level in the boiler can be kept constant, or nearly so; it being sufficient to regulate the pump in such a way that the amount of steam utilized and escaping be replaced by an equivalent volume of water.

The pressure necessary to carry an ordinary sized man is three atmospheres and a half. Belts of cord or leather, or a chain can communicate the movement to the wheels. The inventor claims that he has discovered a new principle of superheating with dry steam, and of the transformation of the latter into work; the problem being to force, in a given

time, the greatest amount of heat into the boiler, consequently to transform water into wet steam, the wet steam into dry steam, the latter into heat, and the heat into work. In heating a boiler containing water, each molecule should absorb a given amount of caloric; the

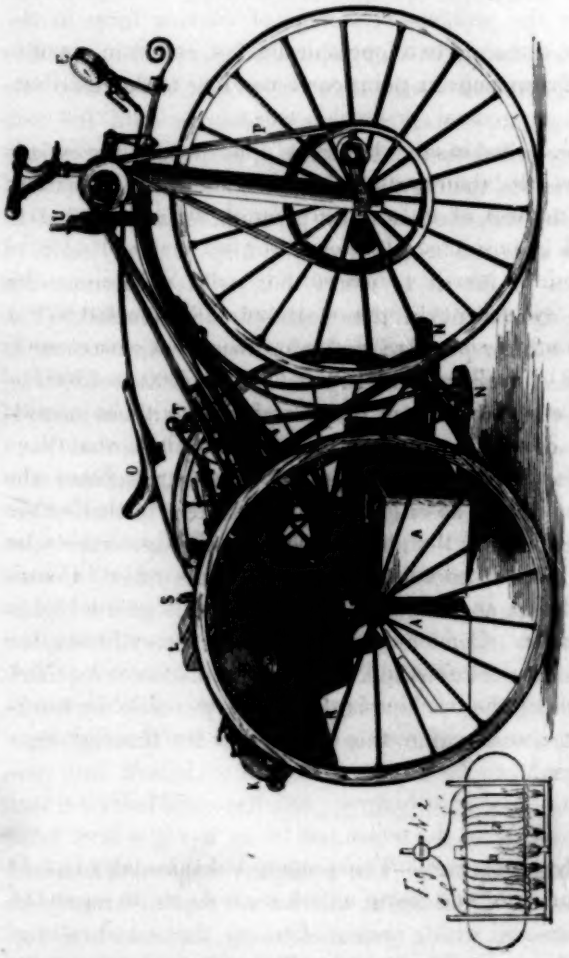


Fig. 1. General View.
T—cylinder.
G—reservoir for water.
A and *A'*—box for storage of luggage.
N and *N'*—supports for the feet.

Fig. 2. Section of Boiler.
Fig. 2. *B*—generator, covered with a non-conducting surface.
K—gasometer, and *R* the lamp.
O—seat for rider.
E—pressure gauge.
L—chimney of the generator, and *S* the whistle.
U—system to tighten the belts.
P—cord belts placed on each side of the wheel.
D—crank wheel of the motor,

Fig. 2. *a* and *a'* are tubes superheated, coiled in spiral on the boiler.
b and *b'*—show where the tubes unite before the distributor.
c—shows fire-box heated with gas.

greater this absorption, the nearer we are to a solution of the problem. Those in contact with the heated surface will move in consequence of the existing local temperature, and will rise to the surface. Evidently, under these circumstances, the molecules that are submitted

to the greatest heat will be the first to evaporate, and will thereby undergo various transformations, depending upon this heated surface.

Mr. Perreaux considers that the intensity of the heat in the interior of the generator will be proportional to a corresponding decrease in wet steam, and that the pressure augments inversely to the primitive densities. To solve the problem of storage of *vis-viva* force in the centre of a reservoir, there are two long spiral tubes, coiled in opposite directions (see Fig. 2), uniting at a point corresponding to the distributing pipe.

These tubes, being coiled on the boiler, will, as proved by experiment, yield better results than any other known similar combination, as the storage in each ring, even at a low pressure, is proportional to the number of coils.

The inventor goes so far as to assert that, with a thermometer as a test, the *heat* co-efficient in the steam pipe is doubled. For example, the steam at low pressure under ordinary circumstances is 82°C. (179°F.), and in this case is 150 to 160°C. (302 to 320°F.), representing 50 per cent. economy of water and heat, without considering that this type of boiler requires less fuel than those that have been previously adopted. At a pressure of three atmospheres the amount of work that can be accomplished is equivalent to that of six of wet steam. By supposing that the temperature increases the entire length of the coil, the wet steam decreases in the same ratio. Consequently the steam, being at a higher temperature, will give a higher mean effective pressure. Condensation of steam in the cylinders, the inventor contends, no longer exists, and the purging cock is not required. The expense of running the machine is three cents per mile by burning alcohol. What actual value this tricycle or its theories have remains yet to be seen.

The St. Petersburg Canal.—The projected ship canal, to avoid the bar across the mouth of the Neva, will have a depth of nearly 19 feet, and will be connected with a system of basins, docks and railway lines, at an estimated cost of $6,800,000. When it is completed St. Petersburg will become the great commercial centre of Russia, while Cronstadt will be exclusively a military port. At present fully two-thirds of the merchandise destined for the capital has to be transhipped at Cronstadt into small vessels.—*L'Ingen. Univ.* C.

CELLULOID—WHAT IT IS, AND HOW IT IS MADE.

By W. H. Wahl, Ph.D.

The multifarious uses which this remarkable substance is made to serve, and which appear to be constantly increasing, as well as the fact that but little is generally known concerning its composition or the methods of producing it, render it probable that a few words concerning it may prove of interest to many of our readers.

Celluloid, briefly defined, is a species of solidified collodion, produced by dissolving gun-cotton (pyroxylin) in camphor with the aid of heat and pressure.

The nature of this product and the methods of procedure employed in its manufacture will be found described in what follows. First, let us devote a few lines to an account of the materials employed; and here, as of prime importance, we must begin with gun-cotton.

When cellulose, or wood fibre (under which terms are included common cotton, paper or paper-pulp, the refuse of cotton mills and vegetable fibre of every description), is immersed for a few minutes in a bath composed of a mixture of strong nitric and sulphuric acids, then removed and washed and dried, it will be found to have acquired new and remarkable qualities. In external appearance there is nothing to indicate that any change has taken place, but when the test is made it will be found to have become highly inflammable, and (if the action of the bath has been sufficiently prolonged and intense) even highly explosive. Wood fibre, or, to give it its proper chemical name, cellulose, thus treated, is said to have been nitrated, and the resultant product is termed nitro-cellulose, pyroxylin, or, properly, gun-cotton. The latter term is given to it because, when properly prepared, it can be used as a substitute for gunpowder, having explosive qualities considerably greater than the latter. A number of substances besides cellulose, when treated in the manner above described, acquire similar inflammable or explosive properties, among which may be named sugar, starch and glycerine; the nitro-compound of the last-named substance being nothing else than that most terrible and energetic of known explosive agents—nitro-glycerine.

Besides acquiring inflammable and explosive properties, our cotton

(supposing, for the sake of illustration, that we have used this common form of cellulose), after treatment as above described, has taken on another quality, namely, that of ready solubility in certain menstrua which are utterly without action on common cotton. For example, it will be found to gelatinize and quickly disappear in a mixture of alcohol and ether, forming a thick, transparent liquid. This is the same material used by photographers, who, in taking a picture, first spread a thin film of this solution, called collodion, upon a glass plate. The ether and alcohol being volatile quickly evaporate, leaving behind a thin, smooth and tenacious membrane or film of gun-cotton, which serves as the medium of holding the sensitive silver compound used in taking the photographic image. It is upon this property of ready solubility of gun-cotton that the manufacture of "celluloid" depends, as we shall presently see; and the secret of its production depends upon the fact that camphor, like ether and alcohol, will readily dissolve gun-cotton. Prof. Seely, so far as the writer is informed, was the first to observe that gun-cotton would dissolve in an alcoholic solution of camphor, and the brothers Hyatt after many experimental trials, succeeded in perfecting and patenting a procedure, whereby camphor, with finely pulped gun-cotton, is made to exert its solvent effect upon its substance, with the aid of heat (fusion) and pressure in a closed chamber (to prevent the volatilization of the camphor). The following is an abstract of their method:

Gun-cotton is ground in water to a fine pulp in a machine similar to that used in grinding paper pulp; the pulp is then subjected to powerful pressure in a perforated vessel, to extract the bulk of the moisture, but still leaving it slightly moist for the next operation. This consists in thoroughly incorporating finely comminuted gum-camphor with the moist gun-cotton pulp in the condition last named. The proportions employed are said to be one part by weight of camphor to two parts by weight of the pulp.

With the camphor and pulp, the patentees further state they also incorporate any pigments, coloring matter, or other materials that may be adapted to the requirements of the articles into which the product is to be manufactured.

The mixture of pulp, camphor and pigments having been made, the next step is to subject the mass to powerful pressure, in order to expel from it the remaining traces of moisture, and incidentally to effect also the more intimate contact of the camphor with the pulp.

The dried and compressed mass is next placed in a mould open at the top, into which fits a solid plunger. The vessel is next placed in a hydraulic (or other) press, and heavy pressure, applied to the plunger, is brought to bear upon the mixture. While thus under pressure the mixture is heated by means of a steam jacket surrounding the chamber, or by other means, to a temperature of about 300° Fahr.; at this temperature the camphor fuses and, its volatilization being impossible, the melted gum dissolves the gun-cotton pulp, or, to use the words of the patentees, "converts" it. The patentees further state that the process of transformation is rapidly effected when the right temperature is reached, and the product which results in the homogeneous solidified collodion, known as celluloid. After the mass is taken from the press, it hardens and acquires the extraordinary toughness and elasticity which are the distinguishing characteristics of the product; and one of the most noteworthy circumstances connected with it is the fact that a large portion of the camphor which it contains appears to be permanently held or combined with it, if we may use this convenient (though not strictly correct) term, so that its property of volatilization when exposed to the air is practically arrested.

There are several varieties or modifications of the above-named procedure which would require too much of our space to detail. The process commonly employed in the production of celluloid is substantially that which we have given; and the endless variety of colors that the products of celluloid possess are obtained simply by proper admixtures of pigments in the operation of its manufacture; mottled and other peculiar effects require special manipulation, which our technical readers will not find it difficult to understand. It should be remarked, also, that the celluloid made as above detailed can be rendered plastic again, and remolded into any desired shape without further additions.

As to the applications of celluloid, they are legion, and we can only name the more prominent of them.

As a substitute for ivory it is perhaps best known, and has been so successful as to have been for many uses to which this stubstance was formerly put so extensively substituted for it, as to have made serious inroads upon the business of the ivory importers and workers. So perfect is the resemblance of celluloid to ivory that a close inspection is required to distinguish the counterfeit from the genuine. The absence of "grain" is perhaps the readiest peculiarity by which goods

of celluloid may be detected, but, for all practical purposes, it is not only as good, but also in some respects better than ivory for all the uses of that substance. It (celluloid) possesses not only all the strength and elasticity of ivory, but it does not warp nor discolor with age.

On these accounts it is now largely used in place of ivory in making piano and organ keys, billiard balls (said to be equal in elasticity to those of ivory), combs, backs of brushes and hand mirrors, plates for ivorytypes, frames for looking glasses and portraits, handles for knives and forks, whips, canes and umbrellas, and other objects too numerous to name for which ivory is used; and not the least of its advantages as a substitute for this substance is the fact that it can be molded, a property which renders it possible to reproduce the most delicate and elaborate decoration on the articles fashioned out of it at a fraction of the cost of similarly ornamented goods of ivory, and some of the other materials imitated.

Hard-rubber, it is said, is able on account of its cheapness to hold its own against celluloid very well; but tortoise shell, malachite, amber, pink-coral, and other costly and elegant materials are so successfully imitated that an expert must look sharply to detect the original from the copy. In imitation of tortoise shell, it is made in such articles as combs, card-cases, cigar-cases, match-boxes, napkin-rings, etc. The pink-coral, so popular for jewelry, is admirably imitated, and the imitation sold at prices considerably below those of the genuine article; and the same may be said of articles imitating malachite and amber. Mouth-pieces for pipes, cigar-holders and musical instruments, cleverly substituting the last named are quite common.

Celluloid is used also as a substitute for porcelain in making dolls' heads that will stand any amount of hard usage. It is used in place of tortoise shell and hard-rubber for the frames of eye-glasses, spectacles and opera-glasses, for shoe-tips in place of metal, for martingale-rings, emery-wheels and knife-sharpeners. The latest thing in celluloid, and certainly the most novel, is its use, in combination with linen, cotton or paper, for shirt bosoms, cuffs and collars. These goods are possessed of a lustre which very cleverly imitates that of freshly laundried linen; they are remarkably strong, elastic and durable, and are completely impervious to moisture, and of course to perspiration. When soiled they require only to be wiped off with a moistened sponge,

or cloth, to have their freshness restored, and can be made to do service for a long time.

What new uses for this extraordinary product the future may develop no one knows, but it is safe to say from what has already been achieved with it, that its production is deserving of a rank beside that of vulcanized rubber, as one of the most remarkable inventions of the age.—*Journal of Industry.*

THE ALLEGED DECOMPOSITION OF CHLORINE.

Dr. H. Endemann, who has written an article in the "Journal of the American Chemical Society," entitled "A Review of the Latest Investigations on the Dissociation of the Elements at High Temperatures, publishes the following letter from Prof. Meyer:

"ZURICH, d. 28 Sept., 1879.

"SEHR GEEHRTER HERR—In Erwiederung auf Ihr geehrtes Schreiben vom 12 Sept., theile ich Ihnen mit, dass die Mittheilungen der englischen Journale ueber meine Arbeiten welche ueber Gewinnung von Sauerstoff aus Chlor berichten, ohne mein Wissen und gegen meinen Willen veroeffentlicht sind, und das diese Mittheilungen in wesentlichen Punkten voellig inkorrekt sind.

"Hochachtungsvoll, Prof. VICTOR MEYER."

[TRANSLATION.]

"ZURICH, September 28, 1879.

"DEAR SIR—In reply to your favor of September 12th, I would state that the communications in the English journals concerning my investigations, which report the separation of oxygen from chlorine, have been published without my knowledge and against my wishes, and that the said communications are entirely incorrect in essential particulars. Respectfully, Prof. VICTOR MEYER."

Telegraphic Feat.—Not less than 215 despatches, averaging 30 words each, were sent in one hour over a single wire, between London and Birmingham, by means of a quaduplex.—*Fortsch. d. Zeit.* C.

BLAST FURNACE SLAG.

Scattered throughout the iron-making districts of Great Britain are many million tons of scoria, or refuse from the blast furnaces, which is technically known as slag. This slag goes on accumulating at the rate of nearly eight millions of tons per annum, its bulk being some three times that of the iron from which it has been separated. It forms a heavy encumbrance to iron-masters, demanding the purchase of large tracts of land whereon to deposit it, the investment being, of course, wholly unremunerative. There are one or two exceptions to this rule, as at the Barrow Hematite Iron Works, where the slag is tipped into the sea and serves to form land for the works, and at Middlesbrough, where some of the iron works supply slag for the construction of the breakwater and retaining walls in the river Tees. The quantity thus utilized, however, on the Tees is but about 600,000 tons per annum, forming only a small proportion of the whole yield of the district. In some cases, where the iron works are conveniently situated, the slag is carried out by barges and tipped on to banks at high water to form retaining walls or to reclaim land, being thus got rid of. But, as a rule, the labor and capital expended upon this unproductive substance tell heavily upon profits. No wonder, then, that from the first, persistent efforts have been made either to utilize it or to get rid of it altogether. In early times, slag was broken up by hand and used for road-making, and it so continues to be used where it can be had without a heavy cost for transport; but there is only a limited demand for it for this purpose. On the Continent, where stone is scarce, slag plays a prominent part in road-making, as in Silesia and other similarly situated districts. Another direction in which many attempts have been made to utilize slag, both at home and abroad, is to adapt it for constructive purposes, and various schemes have been devised for transforming the highly refractory slag into bricks, sand, and other materials for building. Some of these schemes have proved successful within certain limits; but the peculiar nature of the slag has more generally led to failure, owing either to the difficulty of dealing with it or the attendant expenses. Among the most prominent living scientific investigators of the question was Mr. Bessemer, and about fifteen years since Mr. John Gjers devised a method of granulating

slag, the sand produce being used in place of silicious sand on the pig beds. The practice, however, was discontinued after a time, for technical reasons. Several other practical men have taken an active part in endeavoring to solve the slag difficulty, among them being Mr. D. Joy, Mr. T. Bell, Mr. Lürmann, and Mr. Homer. Some time since Mr. Charles Wood, of Middlesbrough-on-Tees, directed his attention to the utilization of this unproductive material, and after about five years of careful study, experiment and practical research, he has succeeded in effecting the conversion of blast-furnace slag into various forms, and in applying it to several industrial purposes upon a practical and commercial scale. At the time when he started upon his investigations there was no instance of slag being manufactured into a commercial commodity in this country, its only known application being that of road-making. Mr. Wood, however, has succeeded in utilizing it for the manufacture of building bricks, concrete, cement, mortar and slag-wool. The various processes of conversion and manufacture are carried on under Mr. Wood's management at the Cleveland Slag Works at Middlesbrough, which, together with the adjoining Tees Iron Works, belong to Messrs. Gilkes, Wilson, Pease & Co., of which latter works Mr. Wood is also the manager, and whence the slag is obtained. In following the highly interesting processes of conversion consecutively, we must first take our readers to the iron works, where the slag is run from the blast furnaces into two different machines, one of which produces a coarse kind of shingle and the other a fine sand. For making shingle the liquid slag is run direct from the blast furnaces on to a circular, horizontal, rotative table composed of thick slabs of iron kept cool by having water circulated through them. The table, which revolves slowly, carries the slag round to a certain point, by which time it has solidified. At that point it encounters a stream of water, which further cools it, and soon after it comes against a set of scrapers, which break it up and clear it off the table, delivering it into wagons placed below, which convey it away. For producing slag-sand, the slag is run from the blast furnace into a hollow wheel revolving upon a horizontal axis and fitted with iron buckets inside. A bath of water is maintained inside the wheel at the bottom, and is kept in a state of violent agitation by the revolving action. As the molten slag enters the body of water it is immediately disintegrated and assumes the form of sand, the water taking up the heat from the molten slag and giving it off in the shape of steam. A

constant flow of water is maintained into the machine, and the sand is separated from it and elevated to the top of the machine by the bucket plates, which are perforated. Arrived at the upper part of the machine, the slag sand is dropped into a spout, and thence finds its way into wooden wagons, by which it is conveyed to the slag works for manufacture.

The slag works occupy a main building 120 feet long, 50 feet wide, and five stories high, with basement beneath, and engine house, boiler house, and other accessories annexed. This building was constructed of slag cement-concrete, composed of four parts of slag shingle to one part of cement, and it forms a very solid and comparatively indestructible structure. The slag-sand is brought here from the blast furnace and is tipped into stores below, whence it is elevated to the top floor by means of a hoist, which is fitted with an ingenious automatic safety brake designed by Mr. Wood. The special manufacture in this building is that of bricks, and in carrying this out two machines are used, one having been designed by Mr. J. J. Bodmer and the other by Mr. Wood. For the Wood machine the sand is delivered into a hopper through a coarse screen, which retains any pieces of slag or other substances which may have found their way into the sand. Arrived at the floor below, the sand is automatically measured on a revolving cylinder, divided on the outside, and placed at the bottom of the hopper. From another hopper selenitic lime in powder is also measured by a similar contrivance, and the two substances unite in one shoot, where they become mixed in the proportion of ten parts of sand to one of lime. The mixture is carried down a hopper into the pug-mill of the brick-making machine, where the two substances are further incorporated. This machine was designed by Mr. Wood, and is the outcome of considerable experience with another machine to which we shall presently refer, and which it has to some extent superseded. Mr. Wood's brick machine has a horizontal, circular, rotating moulding table, which contains six pairs of moulds, four bricks being pressed at the same time. During the time of pressing—which is effected by direct mechanical pressure—the table remains stationary, and the same time four other moulds are being filled and the remaining four are delivering the pressed bricks. As they are delivered they are taken off the machine by two girls and are removed to an air-drying shed—the machine producing from 11,000 to 12,000 bricks per day. There they remain for a week or ten days, after which they are stacked in

the open air to harden, which occupies another five weeks or so, when the bricks are ready for the market. The bricks thus produced are very tough; they do not split when a nail is driven into them, and are largely used for interior work, for which they are well adapted from the regularity of their surface and other qualities. They find a good market in London, and are not subject to breakage in transit. According to a certificate recently issued from Kirkaldy's testing works, some bricks taken from a stock, three years old, were not crushed until a pressure of 21 tons had been reached. Others taken from a stock four months old were crushed with nine tons pressure, thus showing not only unusual toughness and strength, but that they were greatly improved by age. We thus have the curious anomaly of bricks being made without burning and of a wet season being favorable to the hardening process. The second machine at the Cleveland Slag Works is that of Mr. J. J. Bodmer, and was the first one put up at the works. It is worked by hydraulic power, and has a horizontal revolving table with twelve moulds. The slag sand and the lime are mixed on their way to the machine, but the machinery for effecting the mixing is more complex than that used for Mr. Wood's machine. The rate of production in the Bodmer press is about the same as in the Wood machine, the distinctive difference between the two presses being that the former is worked by hydraulic power, and the latter by direct mechanical pressure, Mr. Wood's machine possessing several advantages over that of Mr. Bodmer. In another department the manufacture of artificial stone is carried on, the stone being moulded into chimney-pieces, window-heads, balustrading, and outside ornamental builders' work generally. The stone is composed of two and a half parts of finely pulverized slag and two and a half parts of ground brick to one part of Portland cement. The mixture is run into moulds and sets quickly, the articles being ready for the market in four or five days. Besides bricks and stone articles, the slag is used for making mortar, cement and concrete. The mortar is a mixture of slag and common lime, the cement being composed of the same materials with the addition of iron oxides. Slag cement also forms the subject of a recent invention by Mr. Frederick Ransome, who has produced some very remarkable results.

Perhaps the most beautiful, and certainly not the least remarkable, outcome of blast-furnace slag is slag-wool, or silicate cotton, as it is also called, owing to its resemblance to cotton-wool. The process origin-

ated, we believe, with Messrs. Siemens Brothers, on the Continent, and the manufacture has been before attempted in England, but, as far as we are aware, has not succeeded. As carried out by Mr. Wood, at the Tees Iron Works, a jet of steam is made to strike against the stream of viscous molten slag as it is run off from the blast furnace. This jet scatters the molten slag into a stream of shot, which is projected forwards near the mouth of a large tube, in which a couple of steam jets cause an induced current of air. This tube opens into a receiving chamber, composed chiefly of wire gauze, and measuring about 33 ft. long by 15 ft. wide and 12 ft. high. As each shot leaves the stream of slag it carries a fine thread or tail with it. The shot, being heavy, falls to the ground, while the fine wooly fibre is sucked through the tube and deposited in the chamber. The appearance of this chamber after a charge has been blown into it is singularly beautiful, the floor, sides and roof being covered with a thick layer of the downy silicate cotton. After each blowing the wool is removed by forks, and packed in bags for consignment to a London firm—Messrs. Daniel Dade and Co.—who make it into mattresses which are used for covering steam boilers and for other purposes where it is desired to prevent the radiation of heat. For this purpose slag-wool is eminently adapted, as it is a very bad conductor of heat, and is, moreover, perfectly incombustible. The make of slag-wool at the Tees Works is about three tons per week, and as during the running of a four-ton slag ball about 1¼ cwt. of slag-wool is made it follows that for producing these three tons nearly 200 tons of slag have to be operated upon. Another useful purpose for which blast furnace slag has been successfully utilized is that of glass manufacture. The vitreous character of slag indicates a resemblance to glass in its composition. It does, in fact, contain the principal components of glass, but not in proper proportions, and those in which it is deficient have therefore to be added with others which are not present. Some years since Mr. Bashley Britten investigated this question, and in the end succeeded in utilizing for the manufacture of glass not only the material, but also the heat of the slag. This latter is a very important point, inasmuch as upon it depends the economy of the utilization, and, therefore, its commercial success. The practical result of Mr. Britten's researches was the establishment by a company, of some works at Finedon, in Northamptonshire, where the manufacture of glass bottles from slag is now and has for some time past, been regularly carried on. The glass works are situated in close contiguity to

the blast furnaces of the Finedon Iron Works, where the Northamptonshire ore is worked, and as the molten slag is run from the furnaces it is conveyed in carriers to the glass works. In these works a Siemens regenerative gas furnace applied to a glass melting tank enables the preparation of the "metal" to be carried on continuously, affording a constant supply to the glass blowers. The ingredients of the glass are fed into the tank in charges of about 500 lbs., the larger half of which is the molten slag, the remainder being the other necessary ingredients, such as sand and alkalies. In the tank these substances are fused and fined, the fused metal flowing through a bridge to the other end of the tank, where there are five working holes, from which the metal is taken by the workmen and fashioned into useful articles in the usual way. For the present the manufacture is confined to wine and beer bottles, of which about ninety gross can be produced per day. So far the results have proved sufficiently satisfactory to induce the company to extend their works, plans for which are in course of preparation. It is proposed to erect not only additional furnaces, but plant for the manufacture of other articles besides bottles, and for these a wide field opens itself. The glass produced is said to be stronger than ordinary glass, and the color can be varied as required, the natural tint being green. Its working qualities are said to be of the highest order, as it comes from the furnace in the best possible condition for the worker. Some bottles made at Finedon were sent to the Paris Exhibition last year, where they obtained honorable mention, a testimony at once to their character. A new method of toughening glass has recently been discovered by Mr. Frederick Siemens, of Dresden, and it is proposed to apply this process to slag glass for the purpose of manufacturing railway sleepers and other articles. Details of Mr. Siemens process are not at present to hand, but, judged by results, it would appear to differ from that of M. de la Bastie, inasmuch as when the toughened glass is broken it does not fly into minute atoms as does De la Bastie's, but simply fractures, somewhat similarly to cast iron.—*London Times.*

Brazilian Telephones.—In Brazil telephonic communication has been established among many of the large plantations, different private parties, and government offices. At Rio de Janeiro Gowen telephones are used for sending messages between the Senate and the lower house.—*Les Mondes.* C.

RANSOME'S NEW HYDRAULIC CEMENT.

As is well known, the materials employed in the manufacture of "Portland" cement are clay obtained from alluvial deposits—such as is to be found on the banks of the Thames and Medway—and chalk, these materials, after being ground together in water (to produce the mixture known technically as slurry) being burnt with coke in a kiln at a high temperature. Of late years the details of this process of manufacture have been much improved, and numbers of the leading firms are now supplying regularly cement having fully twice the strength of that which could be obtained only a few years ago; but notwithstanding this the materials used have remained the same as those employed when Portland cement was first introduced by Mr. Joseph Aspdin, of Leeds, to whom a patent was granted in 1824.

When employed in decorative purposes a great objection to Portland cement is its color, this objection—which is due mainly to organic and other matters mixed with the materials employed—being particularly strong when the cement is exposed to wet or moisture. It was to removing this defect of color, while retaining the other properties of Portland cement, that Mr. Ransome's experiments were first directed, and, as we mentioned in our former notice, he succeeded in the production of a cement which, while having great strength, was absolutely colorless, or which could be tinted as desired.

Mr. Ransome commenced his operations by substituting previously washed kaolin for the Thames or Medway deposits, and burning the mixture in retorts or muffles, so that the material was protected from the direct action of the heated products of combustion. By this means he obtained a beautiful white cement, which in the course of a few hours set remarkably hard, and was capable of receiving a polish resembling Carrara marble. He found also that the material was still further improved by the addition of a portion of soluble silica obtained from some of the natural mineral deposits, such as the beds near Farnham, or preferably from the deposits in the New England States on the other side of the Atlantic. The relative proportions of lime, alumina, and silica which he found to be desirable in the mixture after burning, were: lime, 60 parts; alumina, 12 parts; and silica, 22 parts. When a tinted cement is required instead of a white, the desired color

can readily be obtained by the addition of pigments, such as ochres or iron oxide, during the grinding.

Although the results obtained by the process just alluded to were in every respect most satisfactory, as regards the material produced both in point of hardness and general appearance, it soon became evident that however valuable this cement might be in an æsthetic point of view for decorative and artistic purposes it could not be produced at a price to render it commercially available for the numerous constructive purposes for which the well-known Portland cement is now so deservedly in demand. Under these circumstances, in casting about for the best source of supplies of silica and alumina in a condition most favorable to enable them to combine readily with lime at a comparatively low temperature, Mr. Ransome was led to the conclusion that the very thing required was to be found in any quantity, and capable of being supplied at a cheap rate and in a very favorable condition, as a by-product which is now of little or no value, and that is blast furnace slag, which consists of silica, alumina and lime.

Many attempts have been made by various parties to utilize this material in the process of manufacture of cement, but the cost attendant upon the reduction of the slag to a sufficiently fine state to combine properly with the additional lime with which it had to be mixed, baffled all attempts to produce with it a good cement at a price that could compete with the Portland cement now in general use. The difficulty of dealing with the furnace slag was, however, removed by the invention of Mr. Charles Wood, of the Tees Iron Works at Middlesbrough, who, in the year 1873, obtained a patent for granulating slag by running it direct from the furnaces into water. This granulated slag, or "slag sand," as it was called by Mr. Wood, was found on analysis to contain:

Silica,	38·25
Alumina,	22·19
Lime,	31·56
Magnesia,	4·14
Calcic sulphide,	2·95
Protoxide iron,	·91

The slag sand so produced is of a most agreeable light buff color, and may be easily reduced to the finest powder by pressing between the fingers and thumb, and by mixing one part of it intimately with from one to two parts by weight of chalk or limestone, and burning

the mixture at a moderate temperature, there is produced an eminently hydraulic cement, which compares most favorably with the best manufactured Portland cement of the present day. It may be noted, as an especial advantage attending the employment of slag sand in this way, that, the materials composing it having already been thoroughly burnt together in the blast furnace, the severe burning required in the ordinary process of cement manufacture is rendered unnecessary.

Comparative Tests of Strength between Portland Cement, weighing 123 *lbs. per Bushel, and Ransome's New Hydraulic Cement.*

Age.	Breaking Strain of Samples 1½ Inches Square, giving a Sectional Area of 2¼ Square Inches.	
	Portland, 123 lb. per bus.	Ransome's Patent.
	lbs.	lbs.
2 days,	510	740
3 "	698	870
7 "	818	1170
12 "	.....	1300
15 "	.....	1330
21 "	.....	1440
28 "	936	
3 months,	1056	
6 "	1176	
9 "	1219	
12 "	1229	
2 years,	1325	
3 "	1314	
4 "	1312	
5 "	1306	
6 "	1308	
7 "	1327	

Samples of Mr. Ransome's new cement have recently been carefully tested at the cement works of Messrs. Gibbs and Co. of Grays, under the direction of the manager, Mr. D. Lincoln Collins, and we annex a table, in which the result of these trials are given side by side with those obtained from an exceptionally good quality of Portland cement, the figures relating to the latter being derived from the valuable experiments of Mr. Grant, who by his practical researches has done so much to elevate the quality of Portland cement during late years. It will be noticed that in the table the results relating to the Ransome cement only extend to samples 21 days old; other older samples will,

however, shortly be experimented upon, and we hope to lay the results from time to time before our readers. Meanwhile it may be noted that, even when fifteen days old, the new cement had attained a higher strength than was reached by the Portland cement in seven years, while it is further particularly to be noticed that the Ransome cement shows a steadily increasing strength with age, so that the sample 21 days old was probably far from possessing the tenacity which will ultimately be attained. Altogether Mr. Ransome appears to have produced a very valuable addition to our constructive materials, and we shall watch the future development of his invention with much interest. —*Engineering.*

New Kinds of Plated Sheet Iron.—In Iserlohn, Westphalia, thin sheet iron is plated with alloys of nickel or cobalt and manganese. A half of one per cent. of manganese makes cobalt and nickel very malleable, fluid when melted, and ductile. The plates which are already in the market are beautifully white and brilliant.—*Metallarbeiter.* C.

Local Earthquakes.—The earthquake of Lisbon, in 1755, was felt over a surface of 40,000,000 sq. kilom. (15,366,000 sq. m.) or over a twelfth part of the earth's surface. Such extensive shocks are generally attributed, by geologists, to volcanic action. Observers at the centre of the disturbed area perceive a vertical oscillation; the movements become more oblique on going from the centre, the waves being propagated with a regularity which is not observable in the ordinary local earthquakes of non-volcanic countries. Dr. Thiessing, in discussing some of the Swiss earthquakes, considers the amount of inorganic matter that is brought to the surface by mineral springs. It has been estimated that a single spring in Louëche (Leukerbad) annually brings 4,000,000 kilog. (8,818,485 lbs.) of gypsum to the surface, or about 1620 cubic metres (2119 c. yd.), a quantity sufficient to lower a surface of a square kilometre (1196·03 sq. yds.) more than 16 decimetres (5·25 ft.) in a century. In the valley of Viège there are not less than a score of gypsiferous springs, each of which carries off annually 200 cubic metres (261·6 c. yds.) of mineral. If we think of the thousands of fountains, and the immense duration of their flow, we may form some idea of the importance of the transformation caused by their waters, and the violent superficial oscillations to which they give rise.—*Bull. de la Soc. Indust.* C.

Bower's Rust-Preventive.—Carbonic acid, generated by the combustion of carbonic oxide, is allowed to act upon iron or steel at a moderately high temperature; or, a layer of sesqui-oxide is first produced, and a mixture of carbonic acid and air is afterwards passed over the red-hot metal.—*Berg- u. Hütten-Ztg.* C.

Proposed Adoption of the Egyptian Cubit.—In noticing the labors of the International Bureau of Weights and Measures, Abbe Moigno regrets the choice, as unit of measure, of the ten-millionth of a meridianal quadrant, "a unit fatally indeterminate," since the meridians vary in length. He suggests, as a better standard, the cubit of the Great Pyramid, which represents the ten-millionth of the earth's polar axis. Sir John Herschel made the same proposal, nearly thirty years ago, and it is somewhat remarkable that his views should be now advocated by a leading French scientific journal.—*Les Mondes.* C.

Thermo-Electric Steel Tests.—Carl Barus has studied the thermo-electric disposition and the electric conductivity of steel, in their relations to the hardness of the steel. He finds that if a steel rod of uniform known hardness is broken in two and the two original ends connected with a galvanometer, the hardness of pieces of steel can readily be tested. For if the free ends of the test rod are laid on the sample of steel which is to be tested, and either point of contact is heated (*e. g.* with a small jet of steam), the thermo-current will flow from the test-rod if it is harder, and to the rod if it is softer than the sample.—*Wied. Ann.* C.

Book Notices.

A Manual of Power for Machines, Shafts, and Belts With the History of Cotton Manufacture in the United States. By Samuel Webber, C. E. New York: D. Appleton & Co., 1879. 2 parts; 124 and 105 pages.

This purely technical work is of the highest interest to the cotton manufacturer in the statement of results of many thousands of tests, by a dynamometer, of the several special machines used in this branch of industry. It may be supposed that the various openers, lappers, cards, draw frames, slubbers, ... slashers, looms, etc. etc., are well-

known invariable standard machines in cotton mills, so that comparisons of dynamometer values, ascertained with some supposable uniformity of conditions of machines, belts and lubricators and lubricants, can be instituted. The 87 pages of tables of information of this class then become available and important to cotton mill owner or operator. The tables of summaries of power for cotton mills for production of different grades of goods, would be more satisfactory if real examples of mills actually at work could have been found to corroborate the totals. But it must be admitted that careful detailed estimates of this class do give a close approximation to accurate results. Beside the tests of cotton machinery, a series of tests of machines for other textile substances: woolen, worsted, flax, etc., will be found more or less extensive and useful.

The two chapters relating to shafting and belting are very incomplete in giving information either to the mill operator or to the general mechanician. Neither generally or in detail, are these subjects considered in a practical point of view. The chapter relating to shafting is peculiarly imperfect. Does the author mean to assert that it is good practice to transmit 48 horse power by a long line of two-inch, cold-rolled shafting running 300 revolutions per minute in swivel bearings, placed 17.7 feet apart, with the usual alignment of bearings in a cotton mill? The want of any consideration of the nature of bearings, in the relation of surface to velocity and pressure, and of consideration of velocity to economic dimensions of pulleys and belts—dimensions derived from the power to be transmitted, as well as from some limit of sizes and strength of belts and convenience in operating, makes it questionable if the omission of the chapter would not improve the work as a work of reference.

The chapter relating to belting with its following table is more seriously erroneous yet. There is no great divergence from the facts, in the assumption that an inch wide leather belt in average condition, at a speed of 600 feet per minute, and having a contact with a turned iron pulley of 180° (or half the circumference) will transmit one horse power. But this will *not* occur at another speed or another angle. The writer of the manual asserts "The most scientific writers commit gross errors in treating of this question." On the contrary, all scientific writers are in accord on the subject and are absolutely correct in their deductions. The only question left open by them is: what is the proper coefficient of adhesion of a leather belt to a pulley? With the

usual caution of a computor each writer has accepted as a safe estimate a low value for this fraction, although he may have got a high one by experiment. The conclusions heretofore reached have given what we now know to be inordinate width for belts.

At the risk of prolonging this notice, an attempt will be made to give a popular account of the theory of belt transmission. A leather belt imparts motion to a pulley upon which it is laid and around which the belt is put in motion, because of the adhesion of the leather to the pulley surface in place of sliding over the same. This adhesion arises from the pressure of the belt upon the pulley, and bears a definite proportion to that pressure. What the value of such proportion may be is called the co-efficient of adhesion, or of friction. Thus if a belt were to exert a pressure of 10 pounds per square inch, and if the belt had 35 inches of contact (say a belt one inch wide bearing 25 inches long on a pulley) the total pressure would be 250 pounds. Experiments have shown that about 146 pounds pull must be exerted on such a belt to cause it to slip, and the co-efficient of adhesion becomes $146 \div 250 = 0{\cdot}583$. In the case of a belt imparting motion, however, the pressure is not uniform, as here assumed. As this pressure *proceeds* from the tension on the belt, and this tension obviously differs on the two sides of the pulley (from the loose to the tight side), a gradual change of tension must occur in the belt on the pulling surface; and a gradual increase of pressure, inch by inch, on that surface. Each particular pressure has its own constant rates of adhesion, augmenting the tension to produce greater pressure. The first adhesion being that coming from the strain on the slack side, while the last adhesion completes the total of strains exerted on the tight side of the belt. To use the words of the writer of the manual, "This will be understood by those who know the enormous hold given by passing the rope from a pulley block once [or twice] around a port where the whole surface is in contact."

The force exerted by a belt is the difference between the strain on the two sides. The greatest strain on a belt is equal to the force exerted, added to the strain on the loose side. The greatest strain *proceeds* from the exertion of sufficient strain on the slack side of the belt to give the requisite adhesion. Same as the exertion of some pull on the rope is needful to keep the rope from rendering around the post when a weight is held by a pulley block, as in the writer's supposed case. The adhesion does not vary directly with the arc of the circle with

which the belt is in contact, but it follows a complicated logarithmic equation derived from the summation of the successive increases of pressure on the pulley surface, as the belt passes from slackness to tightness.

The undetermined element in the text books generally is the coefficient of adhesion, and this element is not yet settled. Let us see what effect a variation of the accepted coefficient will have upon the assumption that 600 feet velocity per minute of a 1-inch belt will be the equivalent to one horse power; a condition which calls for the exercise of 55 pounds *excess* of strain between the tight and slack sides of the belt.

In January of 1868, and the following month, there was published in the JOURNAL OF THE FRANKLIN INSTITUTE a paper by Messrs. Briggs and Towne in which it was attempted to show that a high coefficient of adhesion might be accepted as conforming to common practice. The experiments then published gave $f=0{\cdot}583$ (Gen'l Morin in his Mechanics (Bennett's trans. 1860) found $f=0{\cdot}573$ for a maximum of adhesion of leather to iron). Messrs. Briggs and Towne computed tables based on $f=0{\cdot}423$, which have met general acceptance as practical accomplishments.

Taking their value as a probable one, and going downward to $f=0{\cdot}20$, the following table gives the strains corresponding to 55 pounds *force* upon 180° of contact:

I. Ratio of adhesion of leather to smooth iron—assumed.	II. Effective force given by 1 inch width of belting running 600 feet per minute—pounds.	III. Angle of contact upon pulley.	IV. Tension on tight side of belt, derived from data—pounds.	V. Tension on loose side of belt, derived from data—pounds.	VI. Tension on belt—both sides—when at rest—pounds.
0·583	55	180°	65·45	10·45	37·95
0·423	55	180°	74·8	19·48	46·64
0·4	55	180°	77·	22·	49·50
0·35	55	180°	82·5	27·5	55·
0·3	55	180°	90·	35·	62·5
0·25	55	180°	101·1	46·1	73·6
0·2	55	180°	117·8	62·8	90·3

This table simply exhibits that if an inch wide belt, with 180° contact, is strained to the several tensions shown in column VI, and then it is operated so as to give out one horse power at a velocity of 600 ft.

per minute, there will be called into action the respective coefficients of adhesion given in column I.

Perhaps a more ready understanding of the nature of the action of a belt on a pulley may be had as follows. Suppose a short horizontal shaft, resting in bearings upon which there is placed a pulley and a gear wheel, the latter having the same pitch diameter as the outside diameter of the pulley. Suppose a belt one inch wide to be laid over the pulley, having a weight of 55 pounds attached to each end. This belt then becomes in the condition of a belt upon pulleys strained to an initial tension of 55 lbs. Now let $27\frac{1}{2}$ pounds weight be taken from one side of the belt and transferred to the other side, when the strain on the belt will become $27\frac{1}{2}$ pounds on one side and $82\frac{1}{2}$ pounds on the other, giving an unbalanced strain of 55 pounds, which we will suppose to be supported or resisted by a pressure of 55 pounds on the teeth of the wheel. Under these circumstances let this whole system be put in motion at such rate that the velocity of the pulley surface and of pitch line of the gear will be 600 ft. per minute. The strain on the tight side of the belt will then be $82\frac{1}{2}$ pounds, while the strain on gear wheel, *which is transmitted*, is 55 pounds, and the force or power transmitted is one horse power, or $600 \times 55 = 33{,}000$ ft. lbs. per minute. Here the source of power is the adhesion of the belt to the pulley, the belt being strained to $82\frac{1}{2}$ pounds on the tight side and $27\frac{1}{2}$ pounds on the loose side, to secure this adhesion, the $27\frac{1}{2}$ pound tension on the loose side *is employed*. Perhaps less pull on the loose side would answer; how much less can only be found by some experiment. Most mechanics will say that with $27\frac{1}{2}$ pounds pull on the slack side of an inch wide belt it will not "render" or slip on the pulley when $82\frac{1}{2}$ pounds (or 55 pounds more) is loaded on the tight side, but all will admit that at some difference, the pull on the tight side will preponderate over that on the slack side, together with any supposable adhesion. Thus, to transmit 100 pounds, with the initial tension of 55 pounds on both sides, would suppose only 5 pounds strain to be left on the slack side, while 105 pounds would be exerted on the tight side of the belt. Here the belt would certainly fail to hold on the pulley. With the supposed transmission of 55 pounds from a belt strained initially to 55 pounds tension on both sides, and strained when running to $82\frac{1}{2}$ pounds on the tight and $27\frac{1}{2}$ pounds on the loose side of the belt, accurate computation shows, that for 180° contact the value of the coefficient of adhesion is 35 per cent., as set forth in the table.

Careful experiments have proved that belts and pulleys in the condition of workshop practice give a value for this coefficient as high as 0·583; so that a belt initially strained to 55 pounds on both sides will just slip when there is 15·14 pounds on one side and 94·86 pounds on the other, or will not transmit 79·72 pounds.

From the above it will be noticed that the maximum strain on any belt for 180° contact is equal to the initial tension (which may be anything up to the breaking of the belt or its lacing) *plus one-half of the transmitted strain*, whatever that may be; and the load on the bearings and consequent shafting friction is nearly constant whether the belts are transmitting force or not.

There can be no question that Rankine was misinformed when he was told by some practical man that the rough or flesh side of a belt should run next a pulley, and there is also no doubt that the adhesion of a belt is due to close contact and the expulsion of air; but the theory of adhesion consequent to atmospheric pressure will not hold a moment.

At high velocities the adhesion of a film of air to the belt, where entering on the pulley, causes a serious loss of length of arc of contact, while the atmospheric pressure will occasion a somewhat smaller and insignificant gain in length of same arc, where the belt leaves the pulley. These considerations, however, are not important, except at the highest velocities, and their effects have not yet been investigated fully.

But there is another qualification to the effect of belts at high and even moderate rates of speed that imperatively demands application in estimating any tabular statement of the power transmitted by belts at different velocities. Prof. Rankine was the first to notice the effect of the centrifugal tension of a belt. There is exerted upon any belt, at whatever velocity, a centrifugal force, varying directly as the square of the velocity, regardless of diameter of pulleys. Taking the weight of one inch wide leather belting of 7-32ds thickness at 0·0853 lbs. per foot long, it can be estimated that the following will show the results:

Velocity of belt in ft. per min.	0	1000	2000	3000	4000	5000
Centrifugal tension resulting from these velocities—lbs.	0	0·74	2·9	6·6	11·8	18·4

From this it is evident that within the limits of the table in the manual, from 12 to 28 per cent. of the strain assumed in the manual

as admissible on the tight side of a belt, may be demanded to meet the centrifugal tension. In other words, it does not answer to say that a belt which transmits 1 horse power at a certain velocity is capable of transmitting 8·33 horse power at 8·33 times that velocity.

Whatever may be the merit of the machine tests to manufacturers, the value of the turbine tests, divested from illustration or description of the turbines themselves, cannot have a high estimate. This portion of the work is nearly useless except to the competitors at the Centennial Exhibition and in some instances not especially valuable to the individuals exhibiting.

The second part of the book relates to the history of cotton manufacture in the United States, and is chiefly remarkable for its brevity and for the want of original information. B.

KEY TO THE UNIVERSE, or a New Theory of its Mechanism. Founded upon a I. Continuous orbit propulsion, arising from the velocity of gravity and its consequent aberrations; II. Resisting ethereal medium of variable density, with mathematical demonstrations and tables. By Orson Pratt, Sen. 8vo. Salt Lake City. Pp. 118.

A curious, ingenious and suggestive speculation, developed with a greater knowledge of mathematical principles than is usually shown in works of a like kind. It is, however, far from being a complete solution of the Sphinx's problem, and even the points which are most impressive might have been made still stronger, if the author's reading had been more extensive.

On page 23, the "equatorial ethereal semi-diameter of the sun" is nearly the diameter of Laplace's orbit, in which the centrifugal force of solar rotation would balance the centripetal force of orbital revolution. The distance at which a rotating æthereal atmosphere would have the velocity of light is in the asteroidal belt. The depth of a homogeneous solar æthereal atmosphere is about 207,000,000,000 miles.

On page 26, the statement that the æthereal strata "move in circles, parallel to the equatorial plane and at right angles to the solar axis," is a mere hypothesis. It may be true, or it may not. No evidence is offered, either for or against it.

The same may be said with regard to the statement on p. 31, that "the gravitating force is transmitted with the velocity of light," and

the firm belief "that the heating, magnetic, electric and chemical rays, as well as the rays of different colors, are transmitted with equal velocity." Laplace thought that he had *proved* that the velocity of gravitating action must be at least 100,000,000 times as great as that of light. Professor Lovering has suggested the desirability of extending Laplace's discussion, with the help of the results which have been achieved by modern discovery. Chase has identified the velocity of light with the disturbing velocity at the centre of gravity of the Sun and Jupiter.*

The author's knowledge of the nebula hypothesis appears to be limited to Laplace's presentation of it. He, therefore, falls (p. 73) into the common error of thinking that the notion of the satellites of Mars are at variance with the hypothesis, whereas they lend strong confirmation to Herschel's views of the effect of "Subsidence" in a condensing nebula. C.

List of Periodical Engineering Literature. Prepared at the Rogers Engineering Library, University of Pennsylvania, by H. Haupt, Jr.

The work throughout gives evidence of careful research in the matter of the statistics of the various periodicals mentioned, which those familiar with this kind of work will appreciate. Some of the most recent periodicals have not been included, owing, we suppose, to the fact that they were issued after the manuscript had gone to the printer. This work is a valuable addition to every library, as it not only gives a list of the titles of engineering periodicals, but in most instances gives the price of the recent journals, both English and American, by which means library companies, ordering or desirous of ordering, periodicals can arrive at an estimate of the cost and know what journals are extant. It is the cheapest work of its kind, and should be possessed by every library.

In reviewing the above-mentioned work, we would note the omission of the Franklin Institute Library from the list of abbreviations, and would remark in defence of the author that this omission was unintentionally made, and was caused by the haste to which the author was subjected.

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* Proc. Amer. Phil. Soc.; this Journal, ciii, 285-7.

FRICTION AND LUBRICATION. Prof. R. H. Thurston. Published by Railroad Gazette, New York: 1879. 212 pages, 18mo.

Prof. Thurston has in this book collected veritable experimental data from all the accepted authorities, and has supplemented his information by very thorough experimental results with somewhat novel apparatus at the Stevens Institute of Technology at Hoboken. The question of the nature of friction, its distinctive character when divested from conditions of contact, or associated with them; the question of the continuity of film, and the resistance to molecular mobility of various liquid, or semi-fluid substances under varying conditions of temperature; and the question of resistance to rotation of particles of pulverulent or abraded substances, compressed between solid bodies, are those of frictional resistance in the abstract. And the opening for considering these questions broadly, without limited application, is presented with some force by Prof. Thurston. From this point of view the book becomes an eminently valuable addition to technical knowledge. B.

Franklin Institute.

HALL OF THE INSTITUTE, Nov. 19th, 1879.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 210 members and 75 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that fourteen persons were elected members of the Institute at the last meeting. He also communicated a letter of thanks from the Pennsylvania Museum and School of Industrial Art to the Board, for the use of the class rooms of the Franklin Institute by their pupils, and the liberal arrangements in fitting up the same, which letter was read to the Institute by the Secretary.

The following donations to the Library were reported:

Memoirs of the Geological Survey of India. Vol. 14, and Part 1 Vol. 15.

Do. (Palæontologia Indica) Series 12, Part 1, and Series 4, Part 3.

Records of the Geological Survey of India. Vol. 11, Parts 1—4. Vol. 12, Part 1.

Contents and Index of the First Ten Volumes of the Records of the Survey.

Manual of the Geology of India. By H. B. Medlicott and W. T. Blanford. 2 Vols. From the Geological Survey.

Report of the Commissioner of Education for 1877.
From the Commissioner.

History of the First Locomotives in America. By W. M. Brown.
From Lewis S. Ware.

Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac. Vol. 1, Part 1. Tables of Eclipses.
From Prof. Simon Newcomb.

Computation of Time and Changes of Style in the Calendar. By Spencer Bonsall. Philada. From the Author.

List of Members of the Institution of Civil Engineers. London.
From the Institution.

Twenty-third Annual Report of the Board of Trustees of the Water Works to Councils of Cleveland, Ohio. From J. Whitelaw.

Thoughts on our Conceptions of Physical Law. By Prof. F. E. Nipher, Kansas City.

Tornado of April 14, 1879. By J. L. R. Wadsworth and F. E. Nipher.

Report on Magnetic Observations in Missouri, Summer of 1878. By F. E. Nipher. From the Washington University, St. Louis, Mo.

Post Route Maps of Maine, New Hampshire, Vermont, Rhode Island, Massachusetts, Connecticut, New York, Pennsylvania, New Jersey, Delaware, Maryland, District of Columbia, Ohio, Indiana, Illinois, Iowa, Missouri, Michigan, Wisconsin, Minnesota, Texas, Alabama, Mississippi, Arkansas, Indian Territory and Florida.
From W. L. Nicholson, Top. Eng., Washington.

Catalogue and Descriptions of Frederick Krupp's Establishment at Essen, Germany.

Forty-four Detail Sheets of Krupp's Steel Works.

Fifty-nine Photographs of Cannon, Munition Wagons, etc., and Works of F. Krupp in the years 1862, 1873 and 1876.
From Mr. A. G. Buzby, Philadelphia.

Reports of the Secretary of War on the Operations of the Department for the fiscal years ending June, 1877 and 1878. Washington.
From the Secretary.

Report of the International Monetary Conference, held in Paris, Aug., 1878. From the Secretary of State.

Report of the Bureau of Agriculture, Statistics and Mines for 1876. By J. G. Killebrew. Nashville, 1877.

Transactions of the Medical Association of Georgia, 1877 and 1879.
From Dr. W. H. Wahl.

Massachusetts Charitable Mechanics Association. Its Act of Incorporation, etc. From the Association.

Memoirs of the Historical Society of Pennsylvania. Vols. 1 and 7. Collections of the Society. Nos. 1—4 and 6.
From the Historical Society.

Specifications and Drawings of Patents issued from the U. S. Patent Office, May, 1879. From the U. S. Patent Office, Washington.

Hygiene and Medical Reports by Medical Officers of the U. S. Navy. By Joseph B. Parker.
From the Navy Department, Washington.

Instructions to Commanding and Engineer Officers for the Care and Preservation of the Steam-Machinery of Naval Vessels.
From the Bureau of Steam Engineering, Navy Dep't, Washington.

Practical Education. An Address by George Woods. Pittsburg, Pa., 1879.
From Jos. S. Travelli, Pittsburg Western University, Penna.

Annual Reports of the Secretary of Internal Affairs. Part 4, on Railroads, Canals and Telegraphs. 1876—1878.
From the Secretary.

Semi-Centennial Celebration of the Franklin Fire Insurance Co. of Philadelphia, June 25, 1879. From the Company.

Catalogue of a Collection of Books in all Departments of Literature in the Mercantile Library, Philadelphia. From Lewis S. Ware.

Map of the Tenth Lighthouse District.
From Lighthouse Board, Treasury Department, Washington.

The Woolen Thread. A Lecture by Chas. Vickerman. England.
From the Author.

Chemical Composition and Physical Properties of Steel Rails. By C. B. Dudley. From the Author.

First and Second Reports of the Director of the Meteorological Observatory, New York. From Prof. D. Draper, Director.

American Institute of Architects, Proceedings of the Eleventh and Twelfth Annual Conventions. From the Institute.

Teknisk Tidskrift, Stockholm. Vols. 1—6.
From W. Hoffstedt, Editor.

Transactions of the Royal Irish Academy. Vol. 26, Oct., 1878, and Jan., April, June, 1879. Vol. 27, Feb. and April, 1879. Also, Proceedings. From the Academy.

Æneidea, or Critical, Exegetical and Æsthetical Remarks on the Æneis. By James Henry. Vol. 2. Duplin, 1879.
From the Trustees appointed by the Author.

Die Gasteropoden des Meeres. By R. Hoerners and M. Auinger. Wien, 1879.

Mittheilungen der K. K. Geographischen Gesselschaft in Wien, 1878. From the K. K. Geog. Gesselschaft.

Verhandlungen des Naturhistorisch-Medicinischen Vereins zu Heidelberg. N. S. 2d Vol, Pt. 4. From the Union.

1st, 2d, 25th, 30th to 32d, 36th and 46th Annual Reports of the Royal Cornwall Polytechnic Society.
From the Secretary of the Society.

Eleventh Annual Report of the Department of Marine and Fisheries, being for the fiscal year ended 30th June, 1878. Ottawa, 1879, with Supplements 1 and 2. From the Department.

Specifications and Drawings of Patents issued for June, 1879.
From the U. S. Patent Office.

S. S. Fitch. Six Lectures on the Functions of the Lungs. New York.

M. Sigaud de la Fond. Cabinet de Physique Experimentale. 2 Vols.

Martin and Chambers. Philosophical History and Memoirs of Royal Academy of Sciences at Paris. London.

E. Darwin. Zoonomia; or the Laws of Organic Life. Vol. 1, 3d Ed. London.

L'Abbé Vollet. Leçons de Physique Experimentale. 9th Ed. 6 Vols. Paris.

J. G. Macvicar. Elements of the Economy of Nature. London.

L'Abbé Girard. Synonymes François.

James Hamilton. Observations on the Utility and Administration of Purgative Medicines in Diseases. Philadelphia.

W. Eisenlohr. Lehrbuch der Physik. Stuttgart.

A. Seward. Memoirs of the Life of Darwin. Philadelphia.

W. Jones. Physiological Disquisitions on the Natural Philosophy of the Elements London.

W. Jones. An Essay on the First Principles of Natural Philosophy. Oxford.

J. B. Biot. Precis Elementaire de Physique Experimentale. 2 Vols. Paris.

J. E. Smith. An Introduction to Physiological and Systematical Botany. Philadelphia.

M. Pouillet. Eléments de Physique Experimentale et de Meteorologie. 3 Vols. Paris. From Mrs. Chas. Ellis, Philadelphia.

Dr. Samuel Chamberlaine read a paper on the "Raising and Reeling of Silk," and remarks were made on the subject by Messrs. Orr and Bingham.

Profs. Houston and Thomson explained and showed the working of their new apparatus for the "Storage of Electricity," which was discussed by Dr. Rogers and Messrs. Scott, Parker and Nystrom.

Mr. William W. Potts described the process of making the artificial stone blocks used for pavements, etc., the materials being crushed limestone and asphalt. Specimens of the blocks, etc., were exhibited.

Col. Henry W. Gray called attention to his invention for electroplating with gold the strings of the piano, and an instrument so constructed was tried.

Mr. Thomas J. Whitney described his "Hot Blast Oil Stoves," which were discussed by Dr. Rogers and Mr. McCollin. Several styles of the stoves were exhibited.

Dr. Carl Seiler explained the construction of his new "Immersion Section Cutter," two forms of it being shown, and entire sections of the larynx, etc., were thrown upon the screen.

Owing to the lateness of the hour, the Secretary's report was omitted, and attention was simply called to a number of interesting things on exhibition.

Mr. Cartwright asked a vote of the members whether the following amendment to the By-Laws should be published or not:

"In case of a vacancy in the office of Treasurer, it shall be the duty of the Board of Managers to appoint a person to perform the duty of the position *pro tempore*."

On motion, the publication was ordered.

Mr. Hector Orr offered resolutions of regret at the death of Mr. John Wise.

On motion, the meeting adjourned.

ISAAC NORRIS, M. D., *Secretary pro tem.*

RECENTLY PUBLISHED.

KITCHEN BOILER. — The Kitchen Boiler and Water Pipes. A few words on their arrangement and management; more especially their treatment during frost, and how to avoid explosions. By H. Grimshaw, F.C.S. 8vo, paper, 40 cents.

CORLISS ENGINE.—Corliss Engine and Allied Steam Motors working with and without Automa ic Variable Expansion-gear including the latest most improved Engine Designs of all Countries, with special reference to the Steam Engines of the Paris International Exhibition of 1878. For Engineers, Machinists, Steam Users and Engineering Colleges. Translated from W. H. Uhland's work, by A. Tolhausen, Jr., C.E. In folio and 4to. *Ready shortly.*

SCIENCE INDEX.—The Science Index. A Monthly Guide to the Contents of Scientific Periodicals. Consisting of a Classified Alphabetical List of the titles and authors (if known) of articles of scientific or technical interest that have appeared in periodicals during the previous month. Each issue will comprise about 60 quarto pages. It will be sold only by subscription, payable in advance. Price per annum $5.00.

STEEL.—A Treatise on Steel: Its History, Manufacture and Uses. By J. S. Jeans, Sec. of the Iron and Steel Institute. In one large volume, 8vo, with numerous plates and woodcuts. *Ready shortly.*

TABLES OF SPEEDS.—Tables of the Principal Speeds occurring in Mechanical Engineering, expressed in Metres, in a Second. By P. Keerayeff. Translated by Sergius Kern, M.E. 18mo, paper, 20 cents.

HEAT.—A Practical Treatise on Heat, as applied to the Useful Arts, for the use of Engineers, Architects, etc. By Thomas Box. Second Edition. Plates. 8vo, cloth, $5.00.

COAL.—A Practical Treatise on Coal Mining. By George G. André, F.G.S. Complete in two volumes, royal 4to, cloth, containing 550 pages of letter-press and 84 plates of practical drawings. Price, $28.00.

GIRDER-MAKING and the Practice of Bridge Building in Wrought Iron. By E. Hutchinson, M.I.M.E. 8vo, $4.25.

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